ELECTRICAL MACHINERY AND THE PRODUCTION ENGINEER.

Paper presented to the Institution, Birmingham Section, by B. Pringle.

General Uses of Electricity in Production.

DURING recent years there has been a great increase in the service which electricity has given to industry in general. It is natural that the demands made upon it have not been equal in all industries, and that certain industries have extended its use along lines which do not appear in other industries, but wherever electricity is used, it may be claimed that it gives reliability, cleanliness, ease of control, and adaptability. Furthermore, it is usually reasonable in price.

The very general use which the production engineer has made of electricity speaks for itself. Commencing with electric light and power, particularly for motor drive, its use has been extended to welding, heating, and high grade furnace work. It has been employed very generally for plating and in various capacities for testing and measurement. The demands made to-day on the electrical engineer spread out electrical applications to an extremely wide field so that it is increasingly difficult to keep in touch with all these developments. Furthermore, it frequently happens that where progress is steady, the case requires very close attention to detail to grasp the point of its improvement.

We may refer to the effect which the electric motor drive has had upon the layout of the modern machine shop. From the group drive with its overhead belting and shafting to the individual drive of each machine tool with its own motor. In its turn, this new drive exerted a marked effect on the design of the machine tool itself which was probably not contemplated in the first instance.

From the individual driven machine with one motor has been a step towards the sectional motorisation of the machine tool with a motor for each of its principal motions, thus making for mechanical simplicity of the machine tool. This has involved a mechanical design of motor to suit the various mountings involved. A phase beyond this with further simplicity and balanced design is the use of the built-in motor unit, making the motor part and parcel of the machine tool, and even, in some cases, bringing it down on to the final spindle.

The squirrel cage motor originally used as a single speed machine has developed along the lines of giving two, three or four speed changes by building it as a change pole motor, and by such means, speed changes can be obtained simply by using an electrical controller.

It is obvious that these developments have needed close collaboration between the production engineer the machine tool maker and the electrical engineers so that a reasonable balance is struck.

Standardisation of 50 cycle supply.

One of the difficulties of electrical development in the past has been the variety of supply systems and voltages that have been in use. It was, therefore, very difficult to make provision in advance for electrical apparatus when its size and type might be subject to variation for the particular locality to which it was to go.

Now, however, electricity supplies throughout the country are in process of standardisation so that it will tend to eliminate the various voltages and systems which have previously existed, and it is certain that this will have far reaching effects on the trend of development. We shall now have available in most factories a three phase, 50 cycle supply of electricity, usually at 400 to 440 volts, and it is from the possibilities of such a supply that future progress is likely to be made.

Review.

There have been previous papers this year dealing with machine tools, Mr. Garnett dealing with heavy machine tools and Mr. Wright with modern design. This present paper was to cover electrical applications, and where, therefore, it refers to machine tools it omits reference to the ground covered by Mr. Garnett, and whilst Mr. Wright dealt with the machine tool, this present paper refers to the aspect of the electrical drive.

The Squirrel Cage Motor of Constant and Change Speed.

The most popular form of motor for machine tools, sensitive drills, capstan, centre lathes, grinding machines, and milling machines is the three phase, squirrel cage motor which is extremely reliable in use and simple in construction. Its revolving parts are of metallic construction, namely, laminations of iron with conducting bars of metal in slots at the periphery, and even these bars may be cast in of aluminium as in the sample. The only parts that can wear out are the bearings, and they, with normal service, will last pretty well indefinitely. The squirrel cage motor is a constant speed motor (or nearly so) and it has very good overload capacity which is a valuable asset in machine tool work when frequently motors are not required to run for very long periods at full load, but rather

to run for long periods intermittently loaded, and frequently overloaded. Now, the application of the motors to a particular drive is largely a question of the speeds involved, and the adaptability of the general design of the motor.

The squirrel cage motor can be made in two forms, either as a single speed motor or as a change speed motor, and in either case, certain definite speeds can be obtained, and they are as follows:

Single speed of one only of the following	3,000	1,500	1,000	750	600	500
Typical four speed motors	3,000	1,500	1,000			500
		1,500	1,000	750		500

Typical three speed motors—may use any three in the four speed ranges.

These are typical cases, and in the case of change speed motors, other possibilities may be worked.

We have indicated that 500 r.p.m. is the lowest speed; actually, speeds lower than this can be used, for example, 375 r.p.m., but usually it is found that these are uneconomical. The reason for this is that the size of the motor is dependent on the speed, that is to say, a motor of two h.p. at 500 r.p.m. will be a larger machine than a motor of two h.p. at 1,500 r.p.m.

Now, the squirrel cage motor is obtainable in several forms of mounting and enclosure, the most usual being the foot mounted motor, or there is also the flange mounted motor enabling the motor to be spigotted to such as gear boxes. Going a step beyond this, the electrical portions of the squirrel cage motor are so simple that it is possible to supply them as separate units to the machine tool maker to embody them in his own machine tool, the enclosure and mounting of them being entirely dictated by the requirements of the machine tool. One other point; the squirrel cage motor, being very simple in construction, can be thrown instantly from full speed forward to full speed reverse in a very short time, and such an arrangement, therefore, means that they can be used for processes such as tapping. We will refer to that later, but in the meantime go on to a few examples of machine drives which serve as illustrations of what is possible by the use of a squirrel cage motor of one or other designs.

Squirrel Cage Motor Applications.

Coming to various possibilities of motor drive, we will take by way of illustration capstan lathes. First to illustrate a machine in which the final speed makes a direct electric drive impossible. The Herbert 2-S has a final speed of down to 46 r.p.m. and up to 3,090 r.p.m. Between these speeds it has a total of about 44 speeds. It uses a flange mounted three h.p., 1,500 r.p.m. motor, which drives through several gear changes and a stepped cone pulley. It is a machine where all gear changes are obtained by mechanical means.

Secondly, a Ward capstan where again a somewhat similar speed range is required. In its simplest form it uses an eight-speed gear box. Here the motor is foot mounted on a back plate and drives upwards through an inclined V belt drive to the headstock. In this case a four-speed motor is used ; in series with the eight-speed mechanical gear change we get 32 speeds ranging from 33 r.p.m. to 2,700 r.p.m., in a typical case. The controller for the motor speed selection is in front of the machine, handy to the operator.

Thirdly, a case where (due to tungsten carbide tools) the final speed is in line with a reasonable motor speed. The Herbert all-electric capstan has a four-speed headstock, 1,500, 1,000, 750, and 500 r.p.m., in the standard model. Here, a three h.p. stator and rotor change-speed unit is built into the headstock between the main bearings, with a change-speed controller above. A machine where all changes of speed are obtained by electric means and no gear train is used. A manually operated reversing lever is on the front of the headstock. We will refer back to this machine later by way of electric control (Fig. 1).

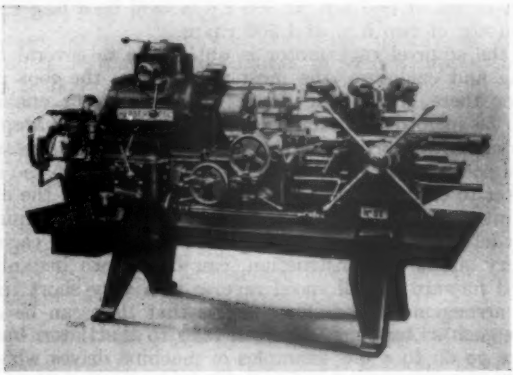


Fig. 1
Herbert electric capstan with electric four speed drive.

Another all-electric machine—a Smallpiece centre lathe—is shown with four, three, or two-speed head ; sometimes built with 3,000 r.p.m. as top speed or with 1,500 r.p.m. as required. It is equipped for high speed turning of the aluminium endrings of squirrel cage rotors. For quick change of work, push button "stop" and "start" is used, and on pushing the "stop" button, electro-dynamic braking is applied, till the button is released. A contactor is on the back of the headstock for this purpose.

Drilling machines are another case and one of the first cases which used change-speed units built direct on to the spindle. The normal drilling speeds encountered may use 1,500, 1,000, 750, or 500 r.p.m. direct as in the plain Archdale head, or again may be combined with a very simple single reduction box to give a total of light speeds down to 105 r.p.m. Occasionally the Archdale electric drill is built for 3,000 r.p.m. top speed. It generally uses an electric suds pump. Similar types of drill are made for example, by Herbert's, where the control gear is over the top of the motor, and a switch handle on the front which may be used " stop," " start," or " reverse " (Fig. 2). In the Pollard electric drill again, a different

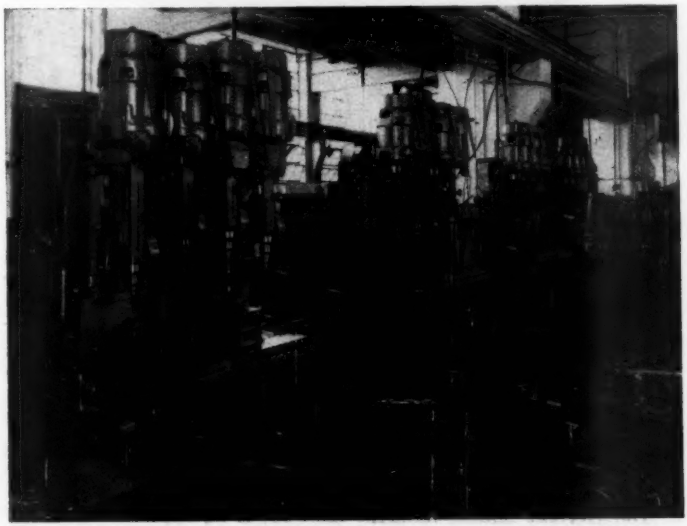


Fig. 2
Four speed electric drills with built in four speed squirrel cage units.

type of controller is used. A button is pressed against an indicator of the particular speed required.

Going over now to grinding machines, larger vertical spindle grinding machines have, in the past, usually been driven by vertical flange mounted motors. The disc size is usually fixed and wear is on the face which does not affect the cutting speed, so that a constant speed motor may be used. On the other hand, the wheel head

spindle needs to be of very massive and rigid construction. A recent Lund grinder is shown which is installed at Coventry Gauge (Fig. 3).

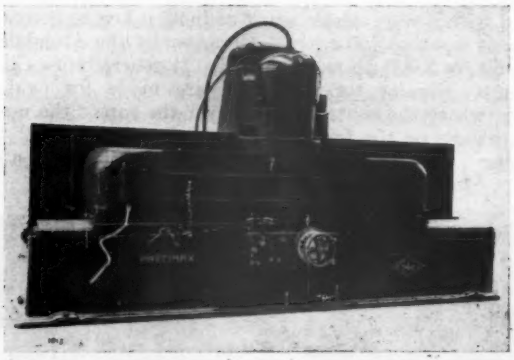


Fig. 3
Lund grinding machine with built in fan cooled electric unit of 40 h.p.

It uses a built-in stator and rotor unit of 40 h.p. at 750 r.p.m. The whole arrangement of head has been made to the ideal mechanical and electrical arrangement. There is the maximum of rigidity and the minimum of bearings, and those dictated by the grinding requirements, not the motor requirements. The motor is totally enclosed but cooled with a blast of air over its outer casing. An ammeter is provided, and that is a very good point because it enables the operator to load up the motor to its maximum capacity and warns him when the wheel is needing attention. The control gear is housed in the base of the machine, and has been built in, leaving no unsightly exposed wiring. Notwithstanding this, the gear is very easily accessible.

The Herbert milling machine (No. 33) is equipped with electric controlled quick traverse and return to the table, and may even be arranged to quick traverse between gaps on the work. Assuming the main motor is running, the operator has only to lift the handle engaging the table traverse, the work is brought rapidly up to the cutter, the normal power traverse taken over automatically, and when the work has passed the cutter the power traverse knocks out in the usual fashion, but the table is quickly returned to the starting position ready for the process to be repeated (Fig. 4).

A small squirrel cage unit is built on to the end of the table, and operates the quick traverse and return. Plunger switches are operated from adjustable stops in a T groove at the back of the table,

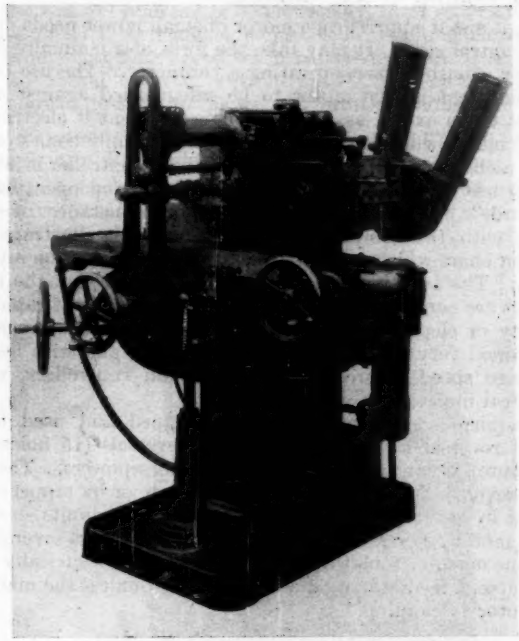


Fig. 4.
Herbert milling machine with power feed from electric unit built in to table end.

but the main power feed to the table is from a gear box finally through a worm. To engage the main drive, the worm handle is lifted and in so doing a selector switch is operated, starting the quick traverse motor which is enabled to overrun the main drive until automatically cut out by the switch stops on the table. Once the work has passed the cutter, the worm handle is knocked down in the usual fashion by its mechanical stop, but in so doing, the selector switch operated from the worm handle reverses the quick traverse motor and returns at high speed (100 inches per minute) until brought to rest by its automatic switch stops. With such a machine, idle time is reduced to a very minimum and an operator can feed more than one machine. (It should be said that when the hand traverse is used, the quick traverse motor cannot be started).

Electric Control of S.C. Motors.

A single speed squirrel cage motor of small power needs only very simple control gear. It may take the form of a manually operated switch or a push button operating a contactor. The use of a contactor may enable the motor to be safeguarded against overload and acts to an extent as a safety device, in that if electric supply fails the motor will not start suddenly after supply comes on again.

With a change speed squirrel cage motor, a controller is necessary. We may use that controller in series with a hand operated switch ("forward," "stop," and "reverse"). An instance of what is possible with this simple method of control is illustrated in an operation chart which is from an actual record taken on an electric capstan. The actual size of the work is not given, but the times on the chart are correct and serve as an illustration of the rapidity and flexibility of electric control. It is suggested that change speeds are obtained very much more simply, quickly, and with less effort by change speed squirrel cage motors and controllers, than by mechanical means.

The squirrel cage motor may be designed and used for very frequent reversal for tapping duty—30 reversals (15 holes tapped per minute) is practicable with small horsepowers. The motor may be reversed by manually operated switch, or by tappet switches operated by the tapping spindle with adjustable limits so that the tapping motor reverses on reaching the limit. Where several motors are on one machine tool, they may be interlocked electrically so that, for example, a feed motor cannot start or run unless the main workhead motor is running.

The Variable Speed Motor.

Now, in the general matter of machine tool drive we have discussed it using squirrel cage motors giving constant speeds or change speeds in definite speeds. There are cases where it would be very convenient if we could use a type of motor giving a gradual variation of speed between slow speed and full speed. This is possible with a direct current motor, but with standardisation of supply at three phase, 50 cycle alternating current, we shall only be able to use D.C. if we use a rotary converter or a generating set. This may be desirable in some special cases, and there are machines—such as grinding machines and planers—which do that now in some cases.

It is, however, possible in larger powers to obtain variable speed without having recourse to direct current motors, and this can be done by using an A.C. commutator motor. That is a type of motor which can be varied in speed by movement of a handwheel only. This controls the position of brushes on a commutator. Such a motor is illustrated driving a wheel turning lathe. Whilst such a motor can be controlled with utmost simplicity, it is a motor having

a commutator and sliprings, and in general is both larger and dearer than the squirrel cage motor. There may, however, be cases where the use of such a machine is justified. Such machines may be used to increase their speed when traversing inwards across a face-plate to obtain constant cutting speeds. This type of motor is used a great deal in the paper and printing industries.

High Frequency and High Speed Motors on Grinding, Drilling, and Portable Tools.

Referring back to the limitations and speeds of squirrel cage motors, it was said that with 50 cycle supply their maximum speed

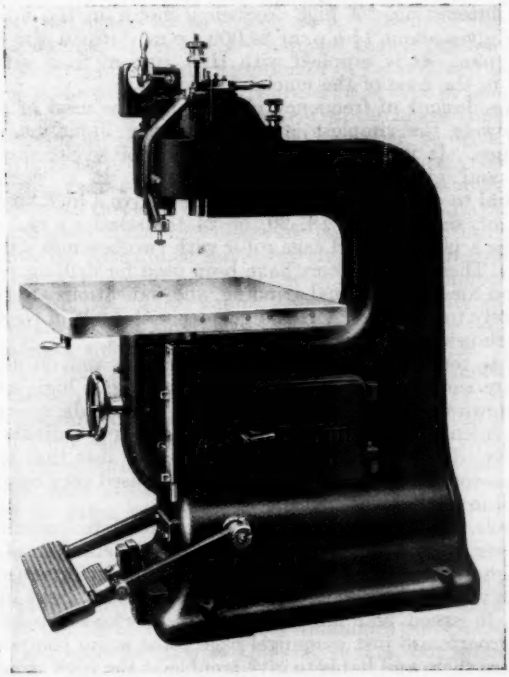


Fig. 5
Wadkin woodworking routing machine with electric head unit, 24,000 r.p.m., and frequency changer built into base.

was 3,000 r.p.m. There are, however, many applications where speeds in excess of this figure may be usefully employed. Small internal grinding and very small drills are such cases. Similar

problems occur in other industries, and they are met by using high frequency squirrel cage motors. If we take a motor which, on 50 cycles, runs at 3,000 r.p.m., it will run at 18,000 r.p.m. when we raise the frequency of supply to 300 cycles. The frequency can be stepped up simply by using a frequency changer to which we will refer.

In textile spinning, thousands of spindles of small power use this system, and run for twenty-four hours a day at speeds of 12,000 and 9,000 r.p.m. In woodworking speeds on routing machines go to 24,000 r.p.m., and are very reliable. We will illustrate a Wadkin router as it has some points of design which may be interesting. A high frequency motor in the head of the machine gives about $1\frac{3}{4}$ h.p. at 24,000 r.p.m. It can also be run at 14,000 r.p.m. It is supplied with H.F. current from a frequency changer in the base of the machine (Fig. 5).

Various designs of frequency changer may be used of which for small powers the simplest is like a slipring induction motor in appearance. It is supplied and driven by 50 cycle, three phase, current and gives high frequency output. It is possible and economical to obtain frequencies which will give a high speed motor a speed of, say, 10, 12, 18, 20, or 24 thousand r.p.m., and that motor has a plain squirrel cage rotor with two bearings only and no gearing. These H.F. motors have been used for drilling very small holes, and for small internal grinding, and indications are that their use is likely to extend. A Heald grinder with built-in electric H.F. drive is shown giving high speeds with no belts.

Portable tools when used in small numbers and on an electric supply are usually single phase motors running at high speed, and coming down through reduction gears to a low spindle speed. They are convenient in that they can connect to any ordinary supply. They have disadvantages consequent on the fact that they have a commutator and brush gear, and if they are used very continuously these will involve maintenance.

Air tools, though low in maintenance, tend to consume much more power. Therefore, with many present installations of portable tools, high frequency power is used and the performance of this system is very high. These tools are very robust, light in weight, constant in speed and have very great overload capacity. The revolving parts are just a squirrel cage rotor so no commutator or brushes are there and liable to give trouble at the high speeds which are used. The H.F. motor generally runs at 12,000 or 10,000 r.p.m. and comes down through a reduction gear to tool speeds of, say, 500 r.p.m. or more.

Suds Pumps

We will go back now to the example previously given of a Lund grinder, and would draw your attention to the coolant supply which

comes from a motor driven centrifugal pump, but it has the feature that the coolant is filtered or settled in a separate large tank which is on wheels and can be wheeled bodily away from the machine for emptying. This is a very good feature and it does help in paying attention to the cleaning away of swarf which in many machines, by reason of inaccessibility, is frequently neglected.

Now, the present high speeds of machining and the large amount of swarf that needs to be removed with many high speed machine tools have directed attention to the provision of a coolant pump with its own motor drive. In going to the motor driven suds pump there are two factors. First, the ideal pump for handling dirty liquids charged with swarf as they frequently are, is the centrifugal pump, and that needs to be driven at a high speed, say, 3,000 r.p.m. for economy. It frequently happens that it is required on a tool where there is no secondary motion of this speed, and the direct motor drive is the ideal solution. Further, this type of pump is not harmed by shutting off the suds supply with the motor running. It has no bearings in the suds. It should, however, be driven by the main electric supply to the tool and may then usually be a three phase, squirrel cage motor. The simplicity and reliability has led to the adoption of this type of suds pump on several of the up-to-date tools shown, even drills, now carrying them. There are types of pump similar in appearance but using single phase motors. Such motors have commutators and brush gear, and these motors usually run much faster than 3,000 r.p.m. They are generally recognised as not so reliable as the three phase pump, and there is no justification for using a single phase motor on the pump when the main motor on the tool is three phase. The centrifugal motor driven pump is the job for work demanding a good flood of coolant at moderate pressure. It can deal with, say, 6, 12, or 20 g.p.m. at up to 14 lbs. per square inch, which is ample for suds in operations other than deep boring. It is extremely reliable and can be tied up with the main motor so that it only runs when that does, and then needs no extra switch.

Thrustors.

We have, up to now, described applications of electric power in the form of rotating motion. There have been attempts to get straight line motion of which the most common is the Solenoid. It has generally been used for such as applying brakes, but we come now to the more recently developed thrustor which is an electric hydraulic unit for giving a working stroke. Three sizes are at present obtainable for 75, 150, and 500 lbs. direct thrust, and a stroke of two, three, and five inches, respectively. The stroke is fairly rapid, say, one or two seconds, but it may, if necessary, be made slower, either on the working or return. We will show an

example of the smaller size, and illustrate its working. It contains a small motor driving a centrifugal impeller working in a cylinder of oil and moving a piston up on the working stroke. As it uses a centrifugal pump it can be stalled without harm to anything, and can be run with full stroke or part stroke. This device is relatively new, and it is considered that it may be very useful as it virtually forms a self-contained hydraulic system without external pipes. It has been applied to several machines, and it is possible to translate the straight line motion to various other motions through suitable link mechanisms—some examples of which are shown on various machines. The device needs to work upright.

Light Ray Applications.

It is usually easy to guard machine tools by mechanical means. There have been cases, however, where fencing itself has proved either difficult or accompanied by certain risks. For some such cases, protection has been obtained by using a beam of light which, if interrupted by the operator, is so connected that the machine cannot operate. A photo electric cell apparatus is used for this, which is, of course, sensitive to light. Similarly, the same device has been used to count articles passing along a conveyor. Articles which, for example, may be irregular in shape or light in weight, and so not applicable to operating a mechanical counter. In the electric application, interruption of the beam of light works a magnetic operated counter.

Electric Welding Machines.

A recent development of electric welding machines is the control of the welding circuit by means of valve circuits. A seam welding machine is shown which uses this system and is working very satisfactorily. Work on similar lines is proceeding both on the Continent and in America. Results appear to justify a considerable future for this system.

An electric seam weld may be regarded as a series of spot welds and if a pressure weld is required, the rate of feed is dictated (amongst other things) by the closeness of those spot welds. If, as is usual, the circuit is interrupted by electro mechanical devices such as, say, a contactor, there is a limit on several grounds to the speed at which such a device can work, and say, at three or four times a second the wear and tear may be considerable. This Thyratron system virtually substitutes a valve system for a contactor and there are no mechanical parts to wear since the time of operation is adjustable just by turning dials. With 50 cycle supply, the times can be adjusted so that welding current passes for $\frac{1}{50}$ second, and is interrupted for $\frac{1}{50}$ second, and either, or both, times may be increased independently of each other by dial turning.

Conversion of Existing Drives.

Whilst we have touched upon the tendencies of development in the matter of machine tool drive, it may well be said that it is not so easy to see what can be done within reason when a factory is already existing and equipped with drives from line shafting. The capital cost of conversion to individual drive in itself is one very serious item apart possibly from the difficulty of seeing just how it is to be accomplished to existing machines. However, where production demands do necessitate machine re-arrangement, the possibility in individual conversions is worth very serious consideration. An opportunity such as a change of frequency scheme may also occur when the power savings possible may merit reconsideration of existing drives along the lines of splitting some group drives to individual drive. From personal observation I would say that a shop converted from group to individual drive is a better, more convenient, and cleaner, and lighter shop to very marked extents, quite apart from power and maintenance saving. We will later show some examples of typical conversions, none of them ideal but indicating that such changes can be done to existing machinery.

Conclusion.

Finally, in the main and earlier portion of this paper we have endeavoured to show the adaptability of the electric drive making for increased simplicity of the machine tool; also the ease and flexibility of electric control of speed and speed changes by means of change speed motors, working either with or without gear reduction.

Discussion.

MR. GRIFFITHS: I have always been under the impression that A.C.variable speed motors have a varying h.p. Low h.p. for low speed and high h.p. for top speed. I want to know, as I am of the opinion that there is a big future for variable speed motors with constant h.p., if this is possible, what is the relative size with ordinary A.C. motors of the same h.p. ? Again, referring to motors and the point that was brought up in relation to altering the cycles in order to obtain another speed, I would like to know if it is possible to make an ordinary four speed A.C. squirrel cage motor into an eight speed motor by changing its cycles from 50 to 100 ? I myself feel there is an enormous future for developments like this, but as I see it at present, the multi-speed motors are very limited. I should like to know if it is possible for a thrustor to be designed of a reasonable size which would move, say, a saddle along a bed weighing, say, 15 or 20 cwt. 14 inches or 15 inches and remain a reasonably controllable job ? Again, I wondered whether there was any field or future for an electric chuck. It seems to be rather foolish to install air to a machine when you have got the main drive on an electric basis. It seems to me also in the control mechanism of braking motors there is a big field for future development. In order to brake a motor, viewed electrically it is quite expensive. One has to put on some fixture with friction surfaces operated by solenoids. I believe at the present time there is a method of reversing the motor, and immediately the reversing takes place the current is stopped, and so stops the motor before any energy is accumulated in the rotor. In any of those directions an enormous field is offered.

MR. PRINGLE: With regard to the first point as to whether a change speed motor can be made with constant h.p. ; the natural characteristic is that the h.p. should increase with the speed. Frequently, however, machine tool people demand a motor of, say, one h.p. at 500 r.p.m., and one h.p. at 1,500. Such motors usually have two windings and it is usually possible to arrange them, if need be, to elevate the h.p. at the bottom speed and reduce the h.p. at the top speed, and thus get the desired compromise. The next point is whether you can change frequency and change speed. Yes, you can, but I doubt if it would generally be economical or efficient. A low speed motor has a large number of poles, but with high frequency work generally motors are used with few poles to get high speeds. Again, other methods would be open when using frequency changers. You could double the number of the motor speeds by altering frequency of output by reversing the excitation

of the frequency changer. The application of a thrustor to moving a slide has not been made within my knowledge. Without doubt, the full possibilities of this are not explored. You mention an electric chuck. I do not know whether you are tying the two things together in your mind, but there certainly seems some possibility that a thrustor might be made to operate a chuck. Electric chucks are being developed (although not to any considerable extent) in Germany, and there is a certain interest being taken in this country at the present time. Just what form that chuck takes is largely at the present in the hands of the machine tool designer. On certain German chucks, for example, the motor rotates a screw. Electric braking of A.C. squirrel cage motors is done pretty extensively in the wood working industry. Generally in machine tool work though, and speeds, say, 1,000 revs., the motor may be allowed to run down free and it is only when dealing with tapping that the current needs to be reversed to stop quickly. In woodworking one may, however, have for example, a planer block of four inches diameter, three feet long running at 5,000 r.p.m., and using electric reversal it may be stopped without jar in two seconds. You can do so quicker if necessary and take steps to prevent the motor running up in reverse. Generally, however, this operation can be easily gauged without this complication. But in machine tool work associated with tapping you not only need to reverse current to stop motor quickly, but to run up in reverse, and frequently there are certain elements of design necessary in the motor.

MR. GRIFFITHS: Could an ordinary standard A.C. motor or multi-speed motor be adapted to a changing cycle? Can you change those cycles and get twice its speed?

MR. PRINGLE: Yes, by using a frequency changer, which is an extra piece of apparatus.

MR. DALMAN: I am interested in this subject solely from the point of view of control equipment, and what can be done by means of such control equipment. I have had the opportunity of handling jobs for many machine tool makers in this country, and I have inside knowledge of some of the things shewn on the screen. Mr. Pringle has brought to our notice the great convenience of the change speed motors from the point of view of quick transmission from one speed to another, and as you saw, very clearly, you can save a good deal of time on a job by this change than by any other means. Similarly, if you wish to stop the motor quickly you can do it by reversing the switch.

With regard to getting quick stops: in actual practice, if you reverse the motor you generally get a quicker stop than you want, and it is often necessary. On machine tools, where you want a quick stop, this is done by plugging. A great deal depends in specific application in adjusting that plugging to give the very quick

stop you required. Normally, it is done by putting resistance in the motor circuit. That is one aspect of the business. Another, is the question of push button control, I think it is fair to say that any movement of a machine tool which a machine tool manufacturer requires to give, or which the production engineer wants can be controlled from a push button station, and it is only necessary for them to state their specific requirements to the control gear manufacturer, and I think you will find he will be able to meet them. There was a point which was raised a minute ago by Mr. Griffiths in connection with the movement of the saddle of a machine through a comparatively long stroke, 14 or 15 inches. It occurs to me it is a job for which a torque motor is admirably suited. Now a torque motor differs from the standard motor, with which you are familiar, in that it is designed to exert pressure while stationary. The only normal application for the torque motor at present (and there are not many in this country) is in connection with brakes. This is a simple motor with a switchgear on the end engaging a tooth segment and so giving a rotary movement of the shaft, which applies the effort to the brake and when that effort takes place, against the control spring. When the power is switched off, the spring pushes the motor back and applies the brake. That type of motor can be applied to the saddle of the lathe in the case Mr. Griffiths mentioned. There is no difficulty in applying it except that you generally have to arrange for a slipping clutch device to prevent shock when the saddle has moved to its final position, and stops dead. On the question of push button control one could go on for a long time, but no doubt other people have something to say.

MR. FENTON: Does Mr. Pringle recommend the use of squirrel cage motors for shop type machines, such as operating machines and power presses? I ask this question because recently I have been up against a difficulty with a heavy operating machine. There has been a change-over of current from D.C. to A.C. supplied by a squirrel cage motor. Originally on D.C. the machine ran very satisfactorily, but after running for a short time on A.C. it began giving trouble. The machine was taken to pieces and all sorts of mechanical parts were examined to try and find out the defect, and then it was finally put down to the fact that the squirrel cage motor did not alter its speed appreciably, and so put considerable strain on the mechanism. Perhaps Mr. Pringle has come across a case of that description.

MR. PRINGLE explained by reference to a curve how the speed of squirrel cage motors could be substantially held or allowed to fall on load with appropriate designs.

MR. WRIGHT: I am very much obliged to Mr. Pringle for confirming practically all I said some months ago, but I have turned one or two points over and should like to raise the point of stand-

ardisation of high cycles. I should like to ask, is there anything done about that. It seems to me that high cycles are no use for portable tools and for things which are going to be made in large quantities if we have no standards. When a motor gets to, say, 7½ or 10 h.p., which is what I am daily concerned with, I seem to rather hesitate about plugging it right on the circuit. I rather think of the effect on moving parts which must be something, and of getting a reasonable start and probably saving the switchgear. I would like Mr. Pringle's idea on that and the general circumstances under which a centrifugal coupling is desirable. I would like to put a little more pressure also on the point Mr. Pringle has mentioned once or twice, and that is the great advantage of using squirrel cage motors, stopping and starting them to suit various movements and to ensure various movements as compared with the methods in use ten or twenty years ago. From the mechanical point of view the squirrel cage motor is a good sound job. There is another point of view for those interested in the mechanical end of machines, not only builders of the machine tools but users. I think we can with certainty look to a greatly increased life of the machine and at the most having to replace a few fairly cheap contact pieces in the control gear rather than dissect the whole machine. I have to add to Mr. Pringle's remarks in reply to Mr. Griffiths, re the thrustor. It seems to me that the thrustor consists of a high speed motor and centrifugal pump for high pressure, and a cylinder for pumping oil used on that pressure, and that the motor and pump might be made as a separate unit, and that the moving of a saddle with it must be quite possible, even for a long distance, and at the same time I agree with Mr. Pringle and other speakers, that the natural way to do that would be to put a one h.p. high torque motor and do it by electrical mechanism rather than introduce the hydraulic feature. Certain firms started making squirrel cage motors in recent years and started off with very small projecting shafts to take the drive, and I have known trouble arise from these. A machine tool maker puts a small pinion about one-third the size of the usual pulley and so overloads the projecting shaft. As a matter of judgment I always prefer those motors with a good substantial shaft.

MR. PRINGLE: You ask if there is any standardisation of high frequency in portable tools. There is, and there is not. Some of these owe their origin to America, and America is associated with 60 cycles and an easy step it is to make a frequent change of three to one, which is 180 cycles, and that is associated with 220 volts. There is another system, which, although American in origin, is associated with 200 cycles, that is, not associated with its American origin but some other voltage, I believe 125. They are the standards in portable tools. In extra high frequency work and 300 and 400 cycles we have some standardisation along 100 volts at 300 cycles

and higher cycles in proportion. That is a very useful figure. I would say that the best centrifugal clutch that I know is associated with the use of powder, or shot in the clutch that seems very good. As regards shaft sizes, that is a matter where there is a certain amount of standardisation, but individual cases can only be judged on their merits.

MR. MALINS: Some years ago, I was interested in a B.T.H. variable speed motor which varied its speed from 80 revs. to 375, with a hand wheel which pulled the brushes on the commutator. That machine was working through a belt at 80 h.p. driving a four cyl. compressor direct, and it gave satisfaction for a couple of years, but the one complaint stated against it was the first cost. Recently I have heard talk of small motors being made the same way and they seem to have application as in your cases now.

MR. PRINGLE: It is true they are an expensive motor, and up to recently have not been developed on lines associated with machine tool work. I am inclined to think that even in machine tool work there are many useful possibilities for smaller motors of the same nature. It is a motor which gives very simple adjustment of speed. I have mentioned one that has just been built now—six h.p.; motors even of this power are used a good deal in the textile industry. It must not be anticipated that a motor of this nature will stand up to the reversing shocks that can be put on to a squirrel cage motor.

MR. WRIGHT: There is a point I should like to reply to. The reversal they get in machine tool work is nothing like as severe as one gets in wood working—where there is a very much higher speed.

A MEMBER asked a question whether variable speed motors had been applied to winding coils in electrical machinery, varying the speed with the diameter of the coil.

MR. PRINGLE: Certainly I have not met a case of this being done, though a very similar thing is done in the paper industry where the speed may be varied with the diameter of a roll of paper.

A VISITOR: I may be under a wrong impression, but does the variable speed motor drop down in stages?

MR. PRINGLE: A variable speed motor of the commutator type varies its speed gradually, and is infinitely variable between its top and bottom limits of speed. A further question was raised regarding whether with the type of electric welding indicated in the latter part of the paper, it was possible to weld thin articles without crimping. I have seen stainless steel about .048 inch pressure welded along the edges to join two sheets, and that remained perfectly flat.

A VISITOR: There is a point as regards electric chucking. In many cases mechanical chucking is far safer than electrical, since a sudden failure of the electricity supply might release the work with disastrous consequences.

MR. DALMAN: In connection with the last speaker's remarks, re magnetic chucking and a possible source of danger, in the event of failure of supply, an automatic change-over on to batteries could be arranged and thus save extensive damage. It would take a very little time and would carry you over the change-over period.

MR. PRINGLE: It is fair to say that we may have been thinking on different lines. I have talked of an air chuck associated with a machine like a lathe, but I think what is really being raised now is the type of chuck which one would call a magnetic chuck. Where, therefore, the subject of an electric chuck had been raised, I had been thinking on the lines of a chuck holding the work mechanically through the mediums of an electric motor. That type of chuck is quite safe.

MR. GRIFFITHS: With regard to these chucks it is quite possible mechanically to lock the jaws so that in case of failure of current the work is still held.

MR. FIELD (Section President): Before actually closing the meeting there are one or two comments which have occurred to me in listening to Mr. Pringle and the various gentlemen who have spoken. There is one very serious complaint against the A.C. change speed motor and its application to machine tools in general. Its lowest speed in ratio of 500 to 460 actually is much too fast for a lot of the tools one has to deal with in the operation work in spite of the tungsten carbide tools which are at one's disposal. It rather seems to help the brass machine with very little else, or perhaps aluminium. Of course, from one point of view the electrical people are rather clever on this change. They bring it along to you and shew how it solves quite a lot of your difficulties. Then you have got to begin to put some change speed device, then an electrical cooling pump, motors for traverses, and I am beginning to think it fatal to get in the hands of the electrical man. One never knows where they are going to stop. The question of the electric chuck, Mr. Pringle made fairly clear in his last remark. The electric chuck is merely an application of a rotary motion developed from a motor attached to the end of the lathe. From there a push gear or pulley rod in the same manner as an air chuck, only a screw on it takes this as it appeared to undo the chuck, as it is just to tighten it up, but when I began to make inquiries for the installation of one of these electric chucks I was rather amazed to find that a chuck 7½ inches diameter with the necessary electric gear added to it cost £180 in this country, and as it was only suggested we fitted it to a machine costing £90, we decided to carry on with air. We get adequate results from an air chuck costing £30. I think the first cost is definitely against the electric chuck, and for the moment at any rate one sees very little future for it.

MR. YOUNGASH : Mr. Pringle has very thoroughly explained the application of electric motors to machine tools, including wood working machines. Personally, I feel there was no need for any apology for the introduction of these, as they have many similarities to metal working machines, and we must all have a clearer conception of the advances, and the advantages that must follow such changes as we know are being made in this direction. One point has certainly been made very clear, that the extremely simple and robust squirrel cage motor can be adopted for many purposes, but Mr. Pringle has shown us very little of the control gear that accompanies these motors, and that in my opinion, is where you begin to get really involved. We have, of course, had some electrical equipment for a long time, magnetic chucks for instance. Many of us know how the windings burn out at times and what happens when the supply of current fails, but we have to admit that these devices enable us to perform operations that would be almost impossible otherwise. No doubt we shall be equally bound to admit the advantages of the simple electric motor when we are entirely familiar with its incorporation in machine tools, particularly if these pretty little push buttons, or rather, the multiplicity of little pieces which are hidden away somewhere behind them prove equally as reliable as the motors. One point that is stressed by the electrical drive enthusiasts is the better lighting and reduced risk in the shops when line shafting and countershafts are dispensed with, but I must remind them that they are silent with regard to the increased floor space they occupy and the probable need for developing an extremely small race of men to adjust and repair the motors they are littering up the floor of our shops with. This, however, is only one small aspect of the question and it is with very great pleasure I ask you to join in offering our heartiest thanks to Mr. Pringle for his interesting and instructive lecture.

THE FUNCTIONS OF A PLANNING DEPARTMENT.

Abbreviated report of Papers presented to the Institution, Yorkshire Section, by James G. Young, M.I.P.E., Section President, and J. Gratrix, M.I.P.E.

MR. YOUNG dealt with the organisation in detail. Beginning with the office of the secretary and accountant, he explained that, under the system he was outlining, co-operation—team-work—was necessary to ensure success. In the secretary's office all customers' orders were serially numbered, reviewed for credit, and then forwarded to the sales department; customers were invoiced on the despatch of material, and the department also collected and disbursed.

The work of the sales department he placed under the following heads: Censors order (for correct wording); corresponds with customer, if necessary; refers to works manager's office, if necessary; quotes prices as required; determines if product must be made or is in stock; promises date to customer (in agreement with the planning department); refers to previous order, if any; specifies despatch route (in agreement with contractor); enters despatch order and follows up orders for despatch; and finally forwards completed orders to office manager.

Referring to the duties of the tool room department, Mr. Young stated that the underlying principle of the planning of this department was to lay out the tools so that whatever products were manufactured the work could be economically done. It was with this object that the tool room department is made responsible for designing jigs, tools, gauges, etc., which will check over to the design of the products, and so minimise incurring any errors before the same goes to the shops. Close co-ordination between designs and tool room is absolutely necessary.

The engineering department should supply all data in complete details including the bill of material; assisting in correct wording of orders; keeping posted to date all engineering data in shops, sales, and all departments; supplies complete set-up plans for machines; estimates costs on new jobs as requested by sales department; returns all customers' orders with complete engineering data to sales department when unstandardised products are required. The duties of the purchasing department he summarised as follows:

Leeds, December 19th, 1933.

Purchases material only on approved requisitions; obtains competitive prices before entering orders; and delivers prices to company; obtains best deliveries; supplies planning department with costs of all materials and services purchased, with the promised dates for delivery to company; keeps in the closest touch with the market conditions; approves invoices for payment and forwards to office manager; and obtains engineering data and specifications as required on purchased materials.

Coming to the production and planning department, Mr. Young presented a system of duties under the following heads:

(*a*) Planning or production manager, who directs all planning, approves all purchases, etc., traces all shipping orders, checks production costs, and keeps list of idle equipment; (*b*) order clerk, who orders all material, procures detail drawing, composes all shop instructions, routes all operations, and consults with shop superintendents; (*c*) stock clerk, who keeps all stock records and sees to replenishment requisitions, etc.; (*d*) shorthand-typist, who types all shop instructions and assists on records, orders, etc.; (*e*) despatcher, who arranges with shops to start all jobs, releases orders, traces all material and all production (in co-operation with shop superintendents), and reports completed orders to cost accountant; (*f*) wages department, which keeps shop pay-roll, checks time cards, extends piece-rates and figures day-rates, checks irregular labour charges, and sees to pay-roll analysis (co-operating with the accountant's office); and (*g*) cost clerk (shop), who keeps account of all costs (labour and materials), estimates costs of new work as required, and reports to office manager monthly.

The duties of stockkeeper he placed under two heads: Receiving and stores. Under the former he receives all purchased material, checks receipts and work, calls for inspections where necessary, handles returned goods, etc., and sends receiving notices promptly through stores to planning department. Under the heading of stores, the stockkeeper keeps all stock orderly, properly cares for all new stock, issues stock only on proper authority, delivers direct to work places, etc. The despatch department duties were seeing to the proper packing, selecting the best and cheapest shipping route, preparing bills of lading, despatching all outside work, and reporting all despatches to the planning department.

The operating side he placed under two heads: Shops superintendents and foremen, and finally, he detailed the duties of the inspector.

Summing up, Mr. Young commented: What is wrong with the world to-day? It is the absence of a proper system of orderly planning. A proper system of planning is essential to success in every sphere of life, and as far as production engineering is concerned, if we plan aright we shall find plenty of work for us to do. Then we shall soon be back to the point where we all want to be.

Subsequently, Mr. Young replying to points raised in the discussion, said he did not pretend to have included everything in the suggestions he had put forward. The subject was too comprehensive to mention every detail in a comparatively brief paper. Referring to a point about consultations with the works manager in connection with orders, Mr. Young expressed the view that in a well-ordered organisation all orders were the province of the sales department. It is the works manager's duty to control the whole of the planning laid out and explained in this paper. In an engineering shop the real trouble was what he might term "bottle-necks." The object of trying to devise a proper system of planning was to locate these "bottle-necks" and eliminate them.

Mr. Gratrix, dealing with the practical side of the function of a planning department, said: I include in my subject the two headings, operation planning and production planning, two things which are not in vogue in most shops, but I think they could be used to advantage in certain types of shops I have in mind. Operation planning is practised in a good number of shops, but on the other hand there are many places where we still have the old follow-up system, where we have a number of progress men who are simply chasing after the work. That system does not save the time that ought to be saved. On the contrary it is practically flogging a dead horse. Planning for production pre-supposes pushing the job in its very early stages and not in the later stages. The planning department is the vital link between design and production. The design department—the drawing office—tells us what we shall manufacture; the planning department how, where, and when we shall manufacture. The planning department should receive the drawings and study the design from the manufacturing point of view. It may frequently suggest changes in detail which materially affect the cost of production without detriment to the design.

Mr. Gratrix went on to illustrate, by means of lantern slides, the value of scrutiny by the planning department, and commented that the slides showed how very essential the scrutiny by the planning department in conjunction with the drawing office was. He proceeded: Close co-operation is also essential between the planning department and the estimating department. The estimating department when quoting for new work should get into touch with the planning department, seeing that the planner is the man who has the most accurate knowledge and experience as to how long it takes to produce a job. I suggest, in all quotations sent out for work which is likely to be ordered in large quantities, or for repetition work, that a record should be kept of the estimate put forward by the planner, so that when the order does materialise he is in a position to go ahead and plan his work so as to turn it out at a profit.

Dealing with production control, Mr. Gratrix said : We all know the old haphazard methods of processing work through the shop. A foreman has not the time, whether he has the knowledge or not, to devote to this planning work in all its details and at the same time keep the wheels running. The foreman's duty is necessarily to keep the wheels running efficiently. Planning can be done much better by the expert, who has all the information in his office tabulated—the machine capacities with their speeds and feeds, all his charts giving speeds and feeds for different materials—and he also has the benefit of the records of past performances of the various methods in use. These are often stored in the cost office, but the expert is always in touch with the cost office and can get the detail when he requires it.

Illustrating a production card with a lantern slide, Mr. Gratrix said it was necessary that all instructions, whether to the machine shop, pattern shop, or elsewhere, should be written and not given verbally. A master card was the basis of the production planners' work. Mr. Gratrix went on : The time required for an operation is fixed at the time the operation planning is done. In the smaller shops the planning of operations could, with advantage, be done by the rate-fixer. As to who actually does this operation, therefore, certainly depends on the size of the shop and its requirements. With regard to the fixing of times, these are worked out by the rate-fixer either by the usual method of calculation or from the records of previous similar operations, and these times form the basis of the production planning which takes place at a later stage. There are various time calculators which can be used, and they are of great assistance to the rate-fixer or planner ; also to facilitate the settling of these rates it is advisable to construct as many charts as possible. Mr. Gratrix added that he was not attempting to go minutely into any particular system because he realised that the system must be designed to suit the requirements of the individual shop. He realised also that very often the introduction of a system into a shop which had existed for years without a recognised system was received with a good deal of obstruction by the older hands. Nevertheless, planning systems to suit each individual shops were practicable and essential.

Proceeding, Mr. Gratrix said : Production planning is rather a difficult thing, but in spite of its difficulties I certainly think it is worth putting into force. The old haphazard method causes nothing but evasion and delay, and although we will not get 100 per cent. efficiency with our production planning system, we undoubtedly will improve on the old method. I submit that it must conduce to smoother running and better and more expeditious deliveries which, of course, are so essential. There can be no doubt that under the

old systems a big drawback has been delays and the consequent annoyance to customers.

Speaking of the various methods adopted for planning different machines, Mr. Gratrix said : In the case of a shop it is very often found advisable to introduce some comprehensive arrangement. Some use a control board—a board with hooks on which the various cards can be mounted in the right sequence. That means you must have a machine-loading chart, whereby it is known how much work there is allocated to every machine. It is rather complicated, but it gives valuable information. It enables you to forecast the amount of labour required and whether overtime is necessary, at the earliest possible moment. Another method on the same lines takes up smaller space, and it has the advantage over the Gaunt chart in that it is easily altered or adjusted. It is what I call a machine-loading rack. But whatever system is devised for recording the machine-loading and the time each job has to be completed in, it must be elastic. It is indeed useless attempting to plan work unless you are working as a team.

In reply to a question raised by Mr. Dove, Mr. Gratrix said : I should place the man in charge of the planning department directly under the works manager, and on a par with the designer and the shop superintendents. In all matters relating to production his word would be law, though I do not suggest that he should be a dictator. His job is to co-operate with the heads of the various departments. If there is to be success, there must be team-work. The head of the planning department would never get results if he took up a domineering attitude. With regard to the design office, I have not found any great reluctance on the part of the designer to listen to suggestions from the planning department. They do not always see eye to eye with you, but the head of the planning department who knows his job will not find it very difficult to convince the average draughtsman.

In reply to another question, Mr. Gratrix said that in regard to the requisite staff for a works of 500 hands, he suggested the need for a man in charge of the production planning to keep the records straight, a planner of operations, and rate-fixers. It was hard to indicate the necessary extent of the staff without knowing the class of work which was being engaged in. Production planning certainly would fully occupy the time of one man—apart from the clerical staff required to link up the various sections of the works.

Mr. R. J. Mitchell, who occupied the chair during the discussion, said the subject of planning was so vast that discussion at a dozen meetings would not exhaust it. He went on to instance experiences from his own diverse engineering career to illustrate the ramifications of the planning problem, and after alluding to one firm which carried out all kinds of " speciality " orders which did not prove profitable,

he remarked that that experience forced him to the conclusion that small businesses at any rate should avoid " specials " like the plague. He believed we were only on the very threshold of scientific planning, but he had one suggestion to make which might be worthy of consideration. It was that it might be possible in a place like Leeds to arrive at some sort of co-operation between the diverse mechanical shops in the city, somewhat on the lines of the bankers' clearing house. He appreciated the great obstacles there would be to the proposal but a kind of mechanical orders clearing-house whereby business not suitable for one firm might be offered to and taken by another firm in the same area, might have the result of keeping work in the city which otherwise would be allowed to go elsewhere. Mr. Mitchell concluded by saying that the Institution of Production Engineers was founded to try to elucidate and promote production as a science, and he would welcome a return to this subject of planning next session when perhaps it would be possible to be a little more precise than had been possible that night. He felt that at the heart of the whole subject there were some classical principles of planning which were universally applicable.

After Mr. F. F. Nurrish, Mr. Dove, Mr. Brownlees, and Mr. Glyde had taken part in the discussion, a cordial vote of thanks was passed to Mr. Young and Mr. Gratrix for their papers, on the motion of Mr. Arnold, seconded by Mr. Ormerod. Mr. Gratrix briefly replied.

MODERN OXY-ACETYLENE PRODUCTION WELDING.

Paper presented to the Institution, London, Eastern Counties, and Western Sections, by C. Helsby, M.I.Struct.E., M.Soc.C.E.(France).

IN 1913 a prominent metallurgist published the announcement that oxy-acetylene welding had no future before it, as the joining of metals together by means of a flame consisting of oxygen and carbon could do no other than produce welds with metals of very inferior qualities, due to serious adulterations of oxygen and carbon.

So much has been done with oxy-acetylene welding since this announcement that it is superfluous to dwell upon the matter longer than it takes to refute such a statement.

Oxy-acetylene welding as a means of joining metals together and producing articles of utility, domestic, commercial, and engineering, has long passed the experimental stage. It has reached a very high pitch of efficiency on the Continent and in the United States of America, and we in this country are paying increasing attention to the process.

On the Continent pressure vessels, such as steam boilers, are being welded by means of the oxy-acetylene process; ships' hulls have been welded by the same means, and there is little doubt that before long this country will follow suit and allow such structure to be fabricated by means of the process. In support of this statement, I would mention that it is not very difficult for the modern oxy-acetylene welding equipment to turn out butt welds on mild steel plate having the following physical characteristics:

Tensile	28.8 tons
Elongation on eight inches ...	22 per cent.
Izod impact	45 ft.-lbs.

With such metal it will be seen that the value of the plate itself is very closely obtained in the weld metal. Such metal can safely withstand severe straining due to impacts and stress reversals without showing fatigue.

Such superiority compels attention from engineers interested in production, but comparative economy must to a large measure govern the choice of joining media.

London, November 3rd; Ipswich, December 5th; Bristol, December 8th, 1933

In order to make oxy-acetylene welding commercially competitive, it is necessary to lay out the work to the best advantage and to make the weld metal do the utmost work by so placing it that it is called fully into play, and yet placed in positions where it can be executed with the least waste of heat and consequently the least loss of gas.

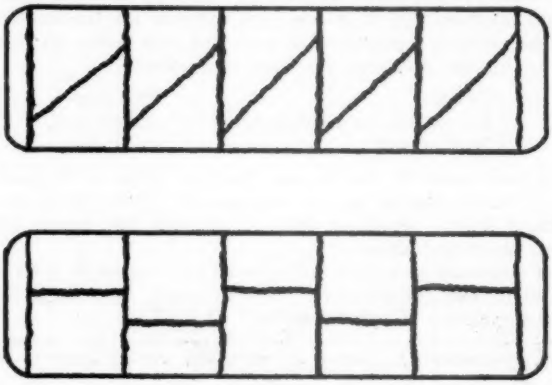
In steel construction over $\frac{1}{8}$ inch thickness, the Rightward method of welding certainly achieves considerable saving over the old method. The Rightward method is shown in the work illustrated in the film.

Oxy-acetylene welding may be of two kinds : the high pressure, where dissolved acetylene is used, or the low pressure, where acetylene is generated from carbide at the works. Both methods give good results, and it is a matter for the production engineer to decide what conditions dominate his choice of system.

In view of the close approximation of oxy-acetylene welds to the parent metal, and also in view of the relative economy of butt welds, the author would recommend that where possible butt welds be adopted, and the full value of the plate be given to the weld, which may be slightly reinforced to give added security, should such, in the opinion of the engineer, be necessary.

Naturally, the calculation of any particular job using butt welds with a unit value equal to the parent metal would be the simplest, and would merely mean that once the cross sectional area of the member or plate had been determined, it would only be necessary to specify the same amount of metal be used in the construction of the butt weld joining the member or plate to those abutting it.

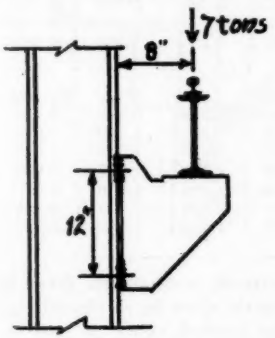
In the case of containers, and in jobs where extra strength of the joint is needed, it is often usual on the Continent to avoid longitudinal seams, and to join plates in the manner shown below :



In the foregoing sketch, it can be seen that the helical weld can be calculated by resolving the lateral bursting tension and the longitudinal bursting tension into the relative components parallel with and normal to the helical seam, as can be followed from a consideration of the sketch.

The film shows the application of this to tank work. It will be observed that the helical weld has been made to take an increased shear load for which weld metal has been proven to be eminently suited.

Corner welds can be fabricated with the same facility as butt welds, and their use is to be recommended for practically any type of construction. The film gives an indication of the practical application of corner welds to rolled steel fabrication of a crane bracket for a five-ton travelling crane. The bracket depends upon corner welds, and is calculated as follows :



Bin $= 7 \times 8 \times 2240 = 126{,}000$ lbs.-in

Length of welds $= 12$ ins./$\frac{3}{8}$ in. butt.

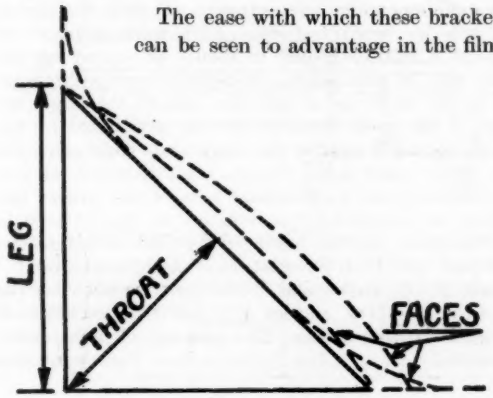
$$\text{Unit shear} = \frac{7 \times 2240}{12 \times 0.375}$$

$= 3{,}500$ lbs. square in.

$$\text{Unit tensile} = \frac{126{,}000}{12 \times 6 \times 0.375}$$

$= 4{,}640$ lbs. square in.

The ease with which these brackets were fabricated can be seen to advantage in the film.



Fillet welding demands considerably more skill of the operator, but with efficient plant such as the multi-flame blowpipe and skilled oxy-acetylene welders, there is no reason why it should not be adopted. In calculating fillet welds, the following method is used :

The actual throat thickness of the weld, multiplied by the length of the fillet, will give the nett cross sectional area of weld metal, and this value multiplied by the allowance unit stress will give the safe working load of the fillet. Fillet welds must always work in pairs, as single fillets, whether cross or longitudinal, are of little value.

The values of such welds are usually taken to equal those given in the table :

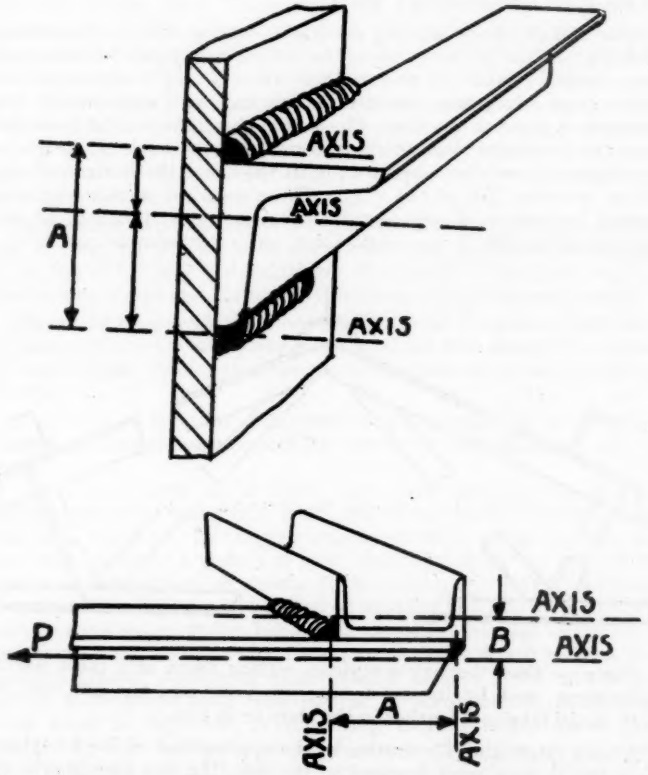
Size of Fillet.	Throat depth and area	Safe Val. of long fillet per lin. inch	Safe Val. of cross fillet per lin. inch	Safe Val. of 45° diagonal fillets	Safe Val. of 30° diagonal fillets	Safe Val. of 60° diagonal fillets	Cubical contents of one lin. inch of weld
Ins.	Ins. and sq. ins.	Tons	Tons	Tons	Tons	Tons	Cu. ins.
$\frac{1}{4}$	0.177	0.841	0.972	0.906	0.884	0.928	0.031
$\frac{5}{16}$	0.221	1.051	1.217	1.134	1.105	1.160	0.049
$\frac{3}{8}$	0.265	1.259	1.458	1.358	1.324	1.388	0.070
$\frac{7}{16}$	0.310	1.474	1.705	1.589	1.550	1.627	0.096
$\frac{1}{2}$	0.354	1.682	1.948	1.815	1.769	1.858	0.125
$\frac{9}{16}$	0.442	2.110	2.432	2.271	2.216	2.323	0.196
$\frac{3}{4}$	0.530	2.508	2.918	2.713	2.644	2.780	0.282

In designing for these welds, the methods of moments must be kept clearly in mind, that is, the fillet welds must be so placed that they make moments equal and opposite to each other around the neutral axis of the members which they support. Thus in the sketch on next page, it will be seen that two fillet welds support an angle on the web of a channel. The moments produced by the weld metal at the end of the angle, multiplied by the distance between the axis of the weld metal and the axis of the angle are equal to the length of the weld metal at the toe, multiplied by the distance between its axis and that of the angle, but their signs are opposite and their sum equals zero. In one plate therefore such a joint is concentric around the longitudinal axis of the angle, but in the opposite plane an eccentricity is induced, as can be seen in the sketch. This, however, can be balanced by fillet welds placed in the positions shown, and their calculation is made as follows :

Let P = the force in the angle, and B the distance between the two neutral axes of the members, and let A = the distance between the axes of the two balancing welds. The amount of weld metal needed will be equal to :

$$\frac{P \times B}{A}$$

and the two fillets will work in equal but opposite directions

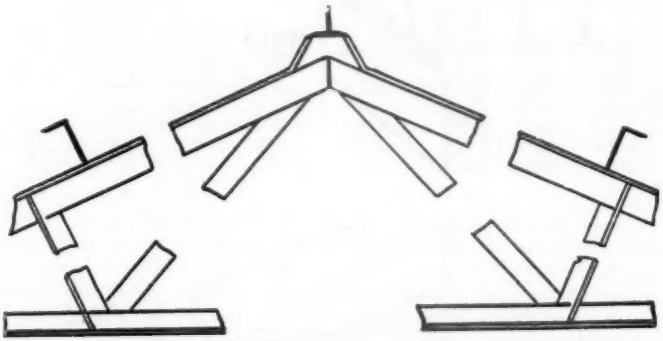


This calculation is most useful for the fabrication of trusses, and is applicable to all rolled sections that are lap welded, for every lap weld introduces eccentricity in at least one plane, which should be balanced by weld metal.

Coming to pipe lines, the production of pipes by welding is developing very very rapidly, and oxy-acetylene welding is holding

its own with other methods of pipe manufacture. The process much in vogue in the United States, called Linde Welding, is shown in the film, and as the welds are butt welded, and the metal approximates that of the parent plate, full value for the welds is given and the calculation merely becomes one of deciding the wall thickness of the plate and ensuring a full weld.

One cannot dissociate oxy-acetylene cutting from ocy-acetylene welding, and the judicious use of the cutting blowpipe often simplifies very intricate welds. A case in point where a very complicated roof truss ridge involving considerable plating and angle work was avoided, is given in the film. The sketch shown hereunder indicated how the horizontal legs of the rafters were cut back by means of the blowpipe and bent upwards until they met the horizontal legs of the inverted Tee of the ridge. These members were easily connected by means of oxy-acetylene corner welds, forming, as can be seen in the film, a very rigid joint, yet a very simple one.



For pipe lines the oxy-acetylene cutting flame is a most useful instrument, and by its use bends, junctions and the like can be very easily fabricated either in the shop or in situ.

A very interesting illustration of the applications of the acetylene blowpipe to pipe work is given in the film. In this part it will be seen that a hole is made in the pipe wall by means of the blowpipe, after which it is enlarged by means of a suitable lever swage, and gradually opened to approximately the desired diameter of the branch line. In the aperture a steel rod of the same diameter as the internal diameter of the junction pipe is inserted, and while the walls immediately surrounding the bar are kept at forging heat, the hole is completed, and after having been trimmed off to the

right height, the junction pipe is placed on to it, and welded by means of an oxy-acetylene butt weld. This method of joining pipes gives free-flowing junctions and is used very considerably for refrigerator work.

For non-ferrous work oxy-acetylene has equally great uses, and the film shows work being executed upon aluminium, bronze, copper and the like. For tipping tools with stellite a surface needing the minimum amount of grinding can be deposited, and a shot in the film shows the action of depositing this metal in process.

Oxy-acetylene mild steel welds come out remarkably well under fatigue tests, and consequently the process enjoys a very considerable popularity on the Continent for the construction of pressure vessels, and the film shows one such vessel containing compressed air on an electric locomotive.

Special rivet cutting heads are used for the oxy-acetylene cutter, and by the use of this tool rivet heads can be removed and the rivets taken out with the minimum of expense. For repair work in engineering shops and shipyards this piece of plant is most useful.

The shells of several boats on the Continent have been fabricated by means of the oxy-acetylene flame, and the film shows the method by which ships' plates can be adjusted by means of the oxy-acetylene blowpipe.

A portion of the film is devoted to the fabrication of aeroplane frames, and good examples of oxy-acetylene welded joints can be seen.

It will have been noted that I have from time to time stressed the advantage of using butt welds where the oxy-acetylene process has been adopted. In the preparation of these welds the practice has been to make a wide Vee joint extending from the root of the plates to the surface, as shown in the sketch A. With the introduction of the Rightward method of welding, the Vee was narrowed and was not taken to the bottom of the plate, but left as shown in sketch B. By comparison of the two sketches it will be seen that a much greater volume of weld metal is needed to fill up the gap left in A compared with that left in B, consequently much more heat must be expended in depositing molten metal for A than for B. It also follows that much greater distortion would result from using A than B, and in actual practice this is found to be the case.

To make a weld with the old method needs roughly 50 per cent. more oxygen and acetylene than is needed to join the same pair of plates together by means of the Rightward method. In preparing for welding, it is very necessary that detailing shall be carried out by the responsible authority, and not left to the man on the job. This may give added work in some cases to the draughtsman

or supervising engineer, but until a settled routine and standardised joints have been obtained in the particular shop, the engineer will not get good results unless the jobs are controlled from inside.

A considerable advance was made by using Rightward welding, and it is claimed in America that the Lindeweld provides a similar advance over ordinary neutral flame welding by the Rightward process. According to the latest information received from exponents of Lindewelding in the U.S.A., the author understands that its cost shows very considerable economies over the neutral flame Rightward method. The film shows very clearly that a carburising flame is needed for this type of welding, and the heat of the flame is used to melt the filler rod which of course rapidly attains molten heat and readily flows into the Vee of the prepared plates. This Vee is even more narrow than that of the Rightward neutral flame welding, so that it will be seen that even less molten metal is needed to join two similar plates than in either the two previous methods of oxy-acetylene welding.

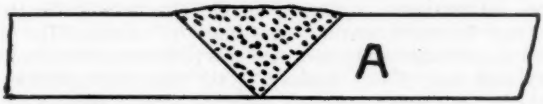
The action of welds under severe tests in practice is very clearly shown in the film.

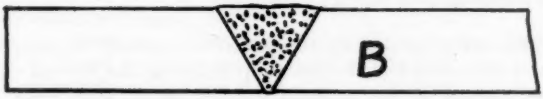
In the author's opinion it is very necessary for a careful consideration to be given to the question of suitable jigs for the fabrication of commercially economical acetylene welded units. With correct design, technique, and simple jigs, oxy-acetylene welding is a commercial proposition, whilst its metal is undoubtedly of very superior quality. The author has endeavoured to stress the point of jig making in the film, and it will be seen that the manufacture of jigs for welded units is not a costly item and that the laying out of a shop for complete fabrication by welding is not more expensive than a similar shop for riveting.

In general, it may be stated that in designing a welded job the engineer should first take out the stresses, either analytically or graphically, as is his usual practice, and then consider carefully what sections will give him the most simple joints, both as regards the amount of welding to be used and the shape and cost of jigs needed for the fabrication of the units. If he decided upon butt-welds, the actual design merely amounts to ensuring sufficient weld metal to equal the cross-sectional area of the members that are being joined, having due regard to any allowances that may be given to relative strengths of weld metal and parent metal. Should lap-welds be used, then he must carefully bear in mind what secondary stresses may be induced owing to the non-axial loading of the joints, and the principle of balancing by moments and couples, as outlined in the paper, is followed throughout the whole structure.

One of the greatest snags constantly encountered in welding is that of distortion which is mostly due to the relief of rolling stresses by the heat necessary to complete the welding. Experiments very

strongly support the theory that the less the heat put into the plates proportionately less will be the distortion. It will be seen from a comparison of the two sketches given below, that B needs





much less weld metal than A and consequently there will be much less distortion resulting from the Rightward weld B, and the cost will naturally be much less.

Discussion: London Section.

MR. G. BAINBRIDGE, JUNR.: I should like to ask Mr. Helsby if he has any figures available regarding the comparative costs of the welded structure compared with the riveted structure of similar capacity and size. There seems to have been considerable saving in weight in the welded structure compared with a riveted structure. Is there more saving in the shops or on the site with a welded structure than with a riveted structure? Could you tell me whether the Continental ship-builders using oxy-acetylene welding use lap welded joints or butt joints?

MR. HELSBY: As regards comparative economy of construction, one can quite safely say that as compared with the riveted structure you can cut out 10 per cent. of weight, and if truss work of any size is encountered you can cut out round about 20 per cent., but the danger is in getting a structure safe but with excessive deflection and giving the appearance of not being safe, necessitating probably some extra members for rigidity purposes; but it is quite usual to save 10 per cent. in weight on the structure itself—quite an ordinary structure. In tank work the saving is about 10 to 12 per cent. Another comparison with tank work is that in welding there is no caulking needed. Ammonia and petrol can be stored in all welded tanks quite easily, and as a matter of fact with the big diameter tanks up to round about 140 feet diameter, welding is about the only suitable means of carrying out those structures. In cost, that is a debatable point at present. I have found that fabricators at the present time are not sufficiently well organised to give the same efficiency in welded structures as they do in bolted and riveted structures. I think it can be safely said that after the first structure sufficient will be learnt in the first job to make an all-welded structure probably 10 per cent. cheaper than a riveted structure of the same type.

As regards shop work, for ordinary welding you can do considerably more shop work than with riveting. That is rather a surprise to everybody concerned. One large fabricator about a year ago objected to welding on the grounds that he may have to shut his shop up. As regards cost, I ran out a comparative cost in Sheffield about three months ago on a building. The building was secured by bolts and rivets, and we went through comparative costs and found that there was only £2 difference in my estimate—but we saved several tons of steel. With the greater use of welding and welded methods in design especially, you will get added advantages.

As regards Continental ship work, the works shown on the film are all butt welds. I understand with regard to the work done in Switzerland that it is all butt welded. Of course the plates have been comparatively thin, but with the Rightward method of welding there is no reason why butt welds should not be used for large ships for where you have metals joined with other metals of the same physical properties you get no concentration of stresses. In my opinion welds produced by the Rightward method, which gives 28 tons per square inch ultimate strength and an izod impact of not less than 40 ft. lb. and a ductility of over 20, you cannot go wrong in welding a ship's plate by means of oxy-acetylene welding and butt welding it. The lap weld in my opinion is a betrayal of lack of faith in welding. There is no need for it at all in oxy-acetylene welding.

Mr. G. A. Robinson (Principal, South-East London Technical Institute): There are one or two points I would like to raise. Mr. Helsby mentioned in the course of his remarks a few words about stainless steel. Has he had experience of any complaints being received when hydraulic anti-blowback valves are used in the acetylene welding of stainless steel? I have heard from one or two people using low-pressure acetylene from generators that when they use the ordinary stock type of hydraulic anti-blowback valve there is a suspicion of water vapour getting over from the water in the hydraulic valve, and it does cause a certain amount of trouble in dealing with stainless steel. As a matter of interest we got in touch with Imperial Chemical Industries and have been trying out in our hydraulic valves different fluids, and with one particular fluid made up by I.C.I. that particular trouble seems to have disappeared.

With reference to his paper, where he mentions the old method of making a weld, I have been interested in that because at our school the position is that the part-time instructor, a practical man, who is lecturing on the theoretical aspect of the situation teaches on this point differently from the four instructors who deal with the practical side. Another point is that during the last three or four months we have been doing a fair amount of experimental work with one or two firms, and just as a matter of experiment we had quite a large number of test pieces made up with exactly the same material and welded under exactly the same conditions. We noticed on mechanical test a great difference in the welded pieces carried out by three or four individuals under exactly the same working conditions and on the same materials. I wondered if our lecturer to-night could suggest any means whereby, where you have a number of men working on the same job, you could obtain uniformity of results. Industrial concerns report definitely on this range of individual efficiency.

MR. HELSBY: I am indebted to Mr. Robinson for his remarks and for his having brought up these questions. About a week ago I was discussing the question of the anti-blowback valve with a manufacturer of low-pressure outfits, and he was of the same opinion as the Imperial Chemical Industries. In all probability that same trouble had been the cause of some stainless steels having been considered as unsuitable for welding by means of oxy-acetylene. Some people will have copper, aluminium, and any other metal but stainless steel welded by means of oxy-acetylene, and it has crossed my mind that this trouble might be the trouble behind the opposition to stainless steel being welded by means of the oxy-acetylene blow-pipe, and although I was not aware that the Imperial Chemical Industries had a liquid that did away with it I must answer his question by saying how grateful I am to know of such a fluid. Some stainless steels are not suitable for welding by means of oxy-acetylene unless this liquid solves it. As regards the lecturer using different methods from the practical man, I would say on the face of it that the theoretical man is using an old-fashioned method.

Regarding individual skill of operatives, that is a tiresome question for the whole of the welding industry. The man who willingly jumps into a bus in London trusts himself to the bus driver's skill quite happily, and then he jibs at the skill of a welder. I think the only solution to that is in thoroughly examining welders and cutting out inefficient work. I have adopted that method throughout my professional career with welding, and I can say quite safely that up to now I have not had any major weld fail. As regards the reliability of welding, Mr. Robinson has not queered my pitch there. I will state that not far from here I visited to-day a works where there are oil pipes carrying oil at 900 lb. to the square inch pressure and a thousand degrees Fahrenheit. Every one of those joints are welded by means of oxy-acetylene and they have been welded for seven years by that means, and they are using the same means to-day to the exclusion of any other type of joints that can be evolved. To ensure that one gets good welds one must have men who are mechanically-minded to begin with and who have received proper training. The unfortunate thing is that people imagine that they can put a blow-pipe into a man's hand and call him a welder. The only solution to Mr. Robinson's problem is see that the skill is uniform, the training uniform, and then, if the man has common-sense, his work will be 100 per cent.

MR. JONES: I should like to ask if Mr. Helsby could recommend what could be done to prevent the hardening up of parents around a weld of malleable castings due to concentration of carbon. I find that the electron metal can be welded if it is in a mass, but when one tries to weld an intricate or delicate structure, fracture

takes place at some adjacent point due to distortion. This can be overcome in aluminium through pre-heating. In the welding of stellite it has been found on quite a number of occasions apparently blow holes appear. There are two schools of thought, one which says it is in the welding and another which says that it is quite definitely pieces removed by the grinding wheel when grinding.

MR. HELSBY : In South Wales a good number of pieces of tools were noted, rather thickly coated with stellite and needed a good deal of grinding, and they betrayed this failing. I would stand by the side that says the trouble is through cutting by the grinding wheel. As regards electron work and malleable castings with the concentration of carbon, a good deal depends upon the flame that you are using with the malleable work. If you are using a carburising flame, and putting carbon into malleable castings in addition, you get concentration. The electron is a subject that is receiving considerable attention in Switzerland, and I would answer that question by saying that the Acetylene and Welding Consulting Bureau officially will communicate the results of those experiments to the Institution of Production Engineers through its secretary.

MR. BAINBRIDGE : With reference to that query by Mr. Robinson in connection with the welding of stainless steel, I am not a metallurgist or a chemist, but I may be able to throw a different light on the subject from the one which has been discussed. I think that one is looking for trouble in the wrong direction. I do not know what effect water vapour would have if it remained in the form of water vapour down the tip of the blow-pipe, but I think that of far more importance is the question of purification of the gas. Most users of acetylene generators do not trouble to purify their gas sufficiently, if they do pay some attention to the question of purification they allow the purifying material to lie in the purifier too long, with the result that the gas is not purified towards the latter stages of the life of the purifying material. That is why dissolved acetylene (that is, acetylene compressed in bottles) is far more suitable for welding stainless steel. I think that if proper attention is given to the purifying material good welds are obtainable with a generator.

MR. HELSBY : I am obliged to Mr. Bainbridge for his explanation. There is not the least doubt that if the purifying material is not attended to periodically, or when it gets foul, it will not purify. One could not expect to have good welds, either steel, stainless steel, copper or any particular metal, if the gases being used were not purified. As regards the relative values of dissolved acetylene and low pressure, one is quite certain that dissolved acetylene is pure, or low pressure is pure, if one looks after the plant. But with oxy-acetylene, or any other welding, you must

have efficient men. If you have an efficient workman who does his job properly, then you have good work.

MR. P. G. ROBERTSON : In the case of welding stainless steel, the parent metal itself is more or less non-corrosive. Do I take it that the actual weld metal placed to make the joint is corrosive ? The metal around the weld normally hardens up, and on machining afterwards about the only method I know is grinding off. Does the flame that is used control this and can it be so adjusted as to make the metal more machinable than it is normally ?

MR. HELSBY : Unfortunately, if you do, you would ruin its stainless qualities : you would make it too soft.

MR. A. A. FRANCIS raised a question as to whether in designing a fabricated structure it was possible to consider it as a homogeneous whole or whether there was any localised stress.

MR. HELSBY : When welds cool down they naturally shrink, and with a badly designed job you may get shrinkage in a compression member which increases the compression. But proper procedure control eliminates that. If you have a weld metal that approximates in physical qualities that of the parent metal you will get no concentration of stresses due to the welding itself. You may get concentration of stresses due to the joints and the position of the members in the structure, but where that happens you make allowance for it. Welding design is very simple indeed, and an engineer can rapidly pick up the principles.

MR. WALTER JONES raised a query regarding the steels used for electrical machine purposes and the permeability of the weld joint.

MR. HELSBY : That depends entirely on the weld as to whether you have a good deal of carbon in it or a little carbon, with oxy-acetylene it is quite possible to produce under ideal conditions weld metal exactly similar to the rolled plate. With oxy-acetylene you are getting the true value of the metal both as regards ductility and ultimate strength and permeability.

MR. C. C. FERGUSON : Has the Bureau considered the question of printing, or having in some concrete form, particulars of the stresses of the different kinds of welds ? For instance, we have bolts and rivets in standard sizes ; we know the shear stresses. Mr. Helsby showed us an illustration of a piece of angle iron with a weld at the top and a weld at the bottom. If that were bolted we should know the shear stresses on the bolts. Has anything been drawn up to show the shear stresses of the different types of welds ? Mr. Helsby mentioned that there was a certain lack of confidence on the part of employers before adopting welds in place of riveted and bolted joints. Is it not because there is no standardised method of testing welds ? Also, has not rigidity in buildings disadvantages over the flexibility which one does get through having bolts and nuts and rivets ? In some cases there are great advantages in having

flexibility in various structures. Are you not asking for fractures to take place when certain types of buildings are too rigid? In regard to pipe-lines, it would be interesting to know when there is a defect in any length of pipe and you have to take one length out, whether it is preferable to take the length out where the weld has been made, or, owing to difficulties, perhaps in welding the two joints together again, whether it would be better to cut the pipe in a different section.

MR. HELSBY: Mr. Ferguson raises some very interesting points. With regard to pipe-lines, my experience of having put in nine miles of all-welded pipe-line with not one leak leads me to believe that if you did have a leak you have a man who does not know his job, and before you embark on putting in pipe-lines you need to be sure that the men do know the job. If you test the work of the men and have an efficient foreman you know just what sort of work to expect. I understand that the pipe-line shown in the picture was something like 120 miles in length. As regards standardised tests, I think the last speaker overlooked the tests that are actually standardised—practically level-pegging with tests for ordinary rolled plates. Then there are the tests that I have given, tests of ultimate strength, in tensility, tests of izod impact, tests of ductility, tests of fillet welds, and tests of butt welds, tests of Tee welds—all those are standardised, and the Bureau would be very happy to supply copies of those standard tests. Coming now to the sketch on page 435 where the speaker called my attention to the fillet welds, he said that he would know the value in shear of bolts or rivets. If you turn to page 434 you will see there is a table there giving the value of fillet welds as explained diagrammatically immediately above it. As regards literature on the subject, the Acetylene and Welding Consulting Bureau have published several pamphlets including one on acetylene which they have distributed fairly widely, and they would be glad to give the last speaker and any other member making application for a copy full instructions of the Rightward method of welding, and I may say that in the course of preparation to-day is a series of books called *The Encyclopædia of Welding*, which is being published volume by volume for fairly nominal figures, and the volume now in print includes full information for structural welding, statics and economics, too, and gives full tables of welded values. I daresay a third volume will be ready for publication probably about Christmas.

MR. C. W. HAMANN: What I have to say may be of some interest to Mr. Ferguson, in answer to his question whether rigid welded joints would be considered an advantage in a structure. The remarks which I am going to make are based on the experience which I have had in New Zealand in regard to structural design against earthquake damage. The New Zealand Building Regula-

tions Committee, which was set up after the disastrous shocks in Hawkes' Bay in February, 1931, has decided from information received from Japan, California and from other centres of seismic activity, that a structure shall resist a horizontal acceleration amounting to one-tenth of the acceleration due to gravity; and, further, that the resultant side thrust, which is the product of the mass of the building and this acceleration, shall act through the centre of gravity of the building. This really means that the side thrust becomes one-tenth of the total weight (dead and live loads) of the building. Thus the structure assumes the form of a cantilever in which are induced very great racking stresses. These can be resisted either by diagonal bracing or, in the portal type, by rigid joints. In buildings it is seldom possible to have diagonal braces on account of windows and other openings in the walls, and in the portal type all the side thrust has to be taken by the resistance to bending of the columns and girders, the bending being transmitted through the joints. I was able to visit Napier and Hastings a few days after the earthquake and there, especially in the reinforced concrete structures, the tendency to fail where there was a concentration of stress at the beam to column connections, was particularly marked. Incidentally, in Napier, a welded steel roof which had spanned a garage that had been gutted by fire, had fallen from its supports and had been greatly twisted by the heat without one of the joints of the trusses failing. Unfortunately, owing to the completely disorganised state of the town, it was impossible to obtain any detailed information about this structure.

It is where concentrated stresses are set up with insufficient material to resist these stresses that failure occurs. To overcome this tendency in a steel framed structure the frame may be designed for riveted construction, to resist the purely vertical or statical loading, and the lateral or dynamic side forces can be taken by the welding of the girder ends to the stanchions, producing thus a rigid frame. It becomes a homogeneous mass; but the flexibility of the columns also allows it to have a certain elasticity. In my opinion, rigid welded joints have definite advantages, of which the application to side thrusts which I have just given, is only one instance.

MR. HELSBY: I would add a few remarks to what the last speaker has said. I am sorry that I cannot reply regarding the rigidity of joints. If you have brittle metal you are asking for trouble. That is why throughout the whole lecture on stressing ductility, izod impact and the like, with metal that has good ductility the fibres can easily readjust themselves as soon as the elastic limit is reached and you have uniformity of stress very rapidly, whereas if you have a non-ductile metal you have high points of stress, and as the elastic limit at this high point is reached you have fracture

causing impact stresses on the other fibres, and rapid failure. I do not agree with the point taken by some engineers, that you need rivets in jointing. If you have to have a pin joint, have a pin joint and design for it, many American bridges have been pin-jointed, and careful observations have been taken quite recently, and it has been proved quite conclusively that the pins never work; they are merely elaborate ornaments justifying the drawing-board. You get a very rigid joint. It is something that you cannot take into account in calculation, and as such you are merely bluffing yourself into false security. In engineering as a science, to try it is pretty well useless. If you have a metal that is as ductile as the parent metal you have an evening-up of the stresses with a free flow of stress and a free flow of the evening influences without any difficulty, and therefore that rigidity can be designed for and you can use rigid beams and portals with the same amount of confidence as you can with reinforced concrete.

MR. G. H. HALES: Mr. Helsby is to be congratulated both on the matter he has given us and for the able way in which he has answered all our questions. One thing that struck me as we proceeded with our questions and answers was the fact that a lot of welding troubles may be traced to the operator, the skill of the operator, and the value of the workmanship put in. I think a lot of people who have use for acetylene welding who have not their own staff of competent operators to perform their work but who rely on outside people who are or are supposed to be experts on the job, sometimes suffer. It would appear to me to be a help and would perhaps help acetylene welding generally if some form of examination and test certificate were insisted on as regards operators.

MR. HELSBY: I should like to answer Mr. Hales' remarks regarding specialists and tests in operators. It is very improbable that a firm specialising in the manufacture of welded structures will have operators who are not highly skilled. Rather the trouble is with people who take welders or start welding without the requisite experience beforehand. I do not think the situation is quite so bad that there is generally an abundance of bad welders. Far from it. The work that is being carried out throughout the British Isles shows very conslusively that the opposite is the case.

Discussion: Eastern Counties Section.

MR. HARTLEY (Section President) said he was sure everyone would agree with him that they had had a most instructive and interesting lecture, and that there were many points to talk about. In their part of the world he believed, more electric welding was done than acetylene welding. He asked the lecturer how the costs compared. Would Mr. Helsby tell him what welding rods he recommended, and did one vary the rods according to the job?

MR. HELSBY replied that there was hardly a pin's difference in the cost of electric or gas welding. There might be a slight saving in speed in gas welding. With regard to welding rods, there were many welding rods on the market to-day made by all the principal gas welding companies, and he was quite sure that if one stated the type of metal one had to weld one would get a good high grade product.

MR. WOODS asked Mr. Helsby if he would advocate oxy-acetylene or electric welding? Which required the greatest skill to operate? How long did it take to train an operator?

MR. HELSBY said that to answer the question as to which method was the better was very difficult. So much depended upon circumstances. It needed a greater outlay to instal an arc welding plant as compared with oxy-acetylene. On the other hand, it depended upon what type of work was to be done. If plates 1½ inch thick, then he would advise arc; if ordinary work, oxy-acetylene should do. As regards the greatest skill, if a man is used to smith work or is a turner or fitter, or a man who is a plumber, the turner or fitter or the like will make a good welder by either arc or oxy-acetylene. Men must be trained. They would spoil several welds at first. For a man used to handling metals, he should learn oxy-acetylene welding in about one month. He should, however, have at least two months' complete training before doing very important work. There is no greater skill in either oxy-acetylene or arc welding. They both need about the same amount of skill and each takes the same length of time to learn.

MR. COPPING said that with regard to welding stainless steel, he had a case in mind where it was desired to weld a square flange about ¼ inch thick with a hole about 3½ inches, on to the main part of a top forging. It was proposed to weld by arc welding process. He asked if there is any greater difficulty in one process as against the other.

MR. HELSBY replied that the weld as suggested would do quite well with the arc and would still retain its properties. It would be well to bear in mind, however, that the top forging should have

the same analysis. This job could also be done very well by oxy-acetylene welding.

MR. WHITE asked the lecturer how the strength of acetylene compared with arc welding. Also, with regard to stainless steel, did it, when welded, lose its stainless property?

MR. HELSBY replied that so far as acetylene welding was concerned, he was quite safe when he stated that with the right method, and with the correct flame, which was easy to maintain, one could get 28 to 29 tons per square inch with mild steel, and this was being obtained every day. With regard to stainless steel, this did not lose its stainless property when correctly welded.

Discussion: Western Section.

MR. WHITEHEAD (Section President): What advantages has acetylene welding over the metallic arc method of electric welding? In the "Lindeweld" installation. How were the joints tested? Welded joints on aeroplane fuselages were shown on the film. I am, however, under the impression that that is out of practice in England to-day, though a lot is done in that way on the Continent. I was in Amsterdam lately and saw quite a lot of it being done. The torch is also used for lining up the fuselage, if they are out they are just set straight by the use of the torch, but I was certainly of the opinion that as far as England is concerned welding is not much used now. With regard to exhaust manifolds, I agree that these are still welded in this country, and I might say I recognised the particular engine shown on the film as being of Bristol design. The exhaust manifolds on that engine to-day are partially welded and partially riveted, but I believe riveting is taking the place of the welding. With regard to aluminium welds, is it not true that at the point of the weld in aluminium, corrosion will take place afterwards?

MR. HELSBY: With regard to the chairman's first question as to the advantages of oxy-acetylene welding over metallic arc welding, I must say I do both kinds of welding and have done a good many good jobs and no bad jobs by electric welding. At the present moment I am having jobs welded, some by oxy-acetylene and some by the metallic arc in order to determine which will work out cheaper. I had this same question asked at Ipswich when I read my paper there at the beginning of this week, and it is a question that cannot be answered straight away. It depends on the sort of work you are doing and the capital you are prepared to lay out. For instance, with an acetylene apparatus, you can also do forging, bending, twisting, setting straight, and all sorts of things you cannot do with the arc. The capital outlay with the arc is about four or five times as much as with the same man-outlay in acetylene. I think all these points should be taken into account. Then again in determining the price of a weld you should remember that with oxy-acetylene welding, butt welding is the most common practice; with fillet welding oxy-acetylene process offers welds that, as far as ductility and Izod values are concerned, are as good as the unwelded metal, butt welds are perfectly safe to use with acetylene welding. Therefore, you should weigh up whether it is better to design for butt welds or whether it is worth while roughing it with fillet welds. Also, as far as strength is concerned in designing for similar loads that for one unit with butt welding you require two units of fillet welding. You should take the total weld and estimate

the costs in that manner. A good deal of thought has to be given as to which method is the cheapest and the price per fillet is no criterion at all. There are so many points to be considered that it makes acetylene welding worth considering by the engineer. At any rate, I can say that acetylene welding is no dearer than arc welding. The building that you saw in the film was the first of its type the contractors had ever done. They had not done any welding at all other than rails round stationary engines. I was fortunate enough to have a free hand in the designing of the building, and I designed for welding throughout with no rivets or bolts, and I specified oxy-acetylene welding. I have the fabricator's authority in saying that as this was the first job of the sort he did, the cost was taken out very carefully and not mixed with other jobs, and as far as the works cost was concerned it was 75 per cent. of his bolt and rivet costs. Out in the field his costs were slightly in excess of his bolt and rivet estimate ; as a matter of fact it was about £10 on the total job. I may say I was rather anxious about how the costs would work out in the field. Certainly the more work you can do in the shops with welding the better it is. In the field it is very difficult to work economically. In the end I settled things by having the clerk of works go out in the field with a drawing-board and design jigs a few days in advance and by doing this we were able to get our costs down to quite a reasonable figure. In fact we were sorry the building was not twice the size, as we were sure then we could have got well under the bolt and rivet estimate. It is remarkable how easily the simple jigs fitted. I think it would have been better if I had not insisted on having no erection holes. I think they would have helped very considerably, and in the next job I should let the fabricator put them.

With regard to the joints on Lindeweld welding, these are not tested excepting where there is any doubt regarding them. Then they have the same tests as any other method, that is pressure testing. The testing of welds is not the bugbear that it was. The best method of dealing with the matter is the one of giving each welder a hand stamp and making him sign his work. As you know, an experienced welder cannot make a bad joint without knowing it, and if he is making a weld that is indifferent he will cut it out and adjust it rather than let a bad joint go through if he knows that he has to sign his work. I must say that I have never had a weld fail—with the exception of two window mullions which were knocked off in an accident—and nobody designs against accidents. One designs for a known stress and no one would design a window mullion to take severe knocks. In any case, such a weld would not do any harm by failing in such a place. Now in Bristol you have had a lot of alterations done at Temple Meads Station, and some hollow mandrels had to be driven in pile frames. These were

designed to take hammer blows, and they were welded, some by oxy-acetylene, and in no case have any of them failed. Prior to welding they were shrunk bonded, snap riveted and fabricated in every conceivable way, and they failed after two or three months. The first welded joint was indifferent and not properly made and failed as soon as it was loaded, but after that not one failed.

With regard to welded aeroplane fuselages, Messrs. A. V. Roe weld every bit of their fuselages from stem to stern, some wings are welded, and some are pressings. I think the Avro machine whether bomber, passenger, or Moth type, can be considered quite a good example and they are all welded. When I was last there I heard of one machine that crashed. When 50 feet up the pilot made a mistake and the machine fell backwards on its tail and disappeared in a cloud of dust and everyone expected to see the pilot crawl out of a smashed machine, but when the dust cleared away he zoomed up the engine and taxied round to the aerodrome gates with his machine like a concertina, and they told me they examined it after for broken joints and not one had failed. I know Fokkers have not yet made a metal machine that has not been welded. The exhaust manifold, of course, is welded, and I am very surprised to hear that there is a tendency to change from welding to riveting on this item at Bristol.

As regards aluminium welds and corrosion at the joints, aluminium is like brass. Very many different compositions go under the same name. The same applies to aluminium. There are dozens of different alloys under the name of aluminium, and it is essential to have the right filler rod, and wipe away all flux after the job is done as it has a corrosive effect on the weld afterwards. This is not always done, and in my experience most cases of corrosion can be traced to faulty cleaning.

MR. CROMBIE: It would appear from the paper that the welded ship has arrived on the Continent. I would like to know the size of these ships, as it seems to be possible that this method would only apply to small ships. Is it likely to apply to ships of, say, 5,000 tons or anything above that?

MR. HELSBY: Definitely the welded ship has come. Take, for instance, the German pocket battleship, that is welded throughout, and by that means on this 10,000 ton ship they were able to mount, I think, 12 inch guns, and thus made it capable of challenging the 40,000 tons capital ships of other navies. At the present moment a number of ships of 10,000 tons are being fabricated partly by means of welding. Small coasters have been wholly fabricated by the same means, and I think it is quite safe to say that the welded ship has arrived. When I was on the Tyne about two months ago, I was shown over a 10,000 ton vessel being fitted out for work between Australia and here. The whole of that vessel's interior

including all bulkheads, some of the decks, all the houses on deck, that is promenades, chart room, wheel house, and mess rooms, are welded, some oxy-acetylene but the majority by arc welding. As a matter of fact for a number of stresses at the present moment, oxy-acetylene welding is excluded by regulations, although the Board of Trade and the other bodies concerned are investigating the question very closely at the present moment, with a view to including oxy-acetylene for all stresses.

MR. HIGGINS : What are the relative strengths of welded joints as compared with riveted joints ? What would be the amount of time saved by the use of the double flame blowpipe as against the single flame ? With regard to the cutting of rivet heads shown on the film, I do not see how rivets could be cut in the manner shown without grave risk of injury to the plates due to burning. It does not seem conceivable to me that mile after mile of pipe line as shown on the film could be assembled without any pressure test. Surely there must be some danger of leakage through occasional pinholes. It seems to me that welded buildings of the type shown on the film must suffer in the way of appearance as compared with bolted or riveted structures.

MR. HELSBY : With regard to the relative strengths of welded and bolted or riveted joints, I would refer to what I said earlier in the evening to the members of the audience, that whereas a riveted joint failed at 5,000 alternations of stress, a welded joint will go to five millions and still be going strong. One registration authority has withdrawn from its specification alternating stress tests for welds because these joints will stand up to rapid alternations of stress almost indefinitely, whereas a riveted joint will usually fail from exhaustion after a series of alternations. Of course, in designing a structure by welding you design for the support of the member. It should also be remembered that you drill a hole in a member for a rivet and this naturally weakens it, and with a riveted joint you get a lump on the side to take the strain, whereas with a welded joint the two members are welded directly together in a straight line, therefore you have a greater lever arm taking stresses round the neutral axis with welded than with riveted joints.

With regard to the saving effected by the use of the double flame as against the single flame blowpipe. Savings of relative cost of from 20 per cent. to 30 per cent. have been effected, it is estimated by this means. I have by the use of the double flame blowpipe succeeded in competing with the arc weld in its own field. As regards the cutting of rivet heads, I have not seen this instrument at work, but I am assured by the engineer who lent me the piece of film that this is the usual practice in German shipyards, and there is no burning of the rivet holes. I may say that in Darlington

earlier in this session, one of the engineers connected with a local works said that he had tried to cut rivet heads but they were not successful. I think they use a very flat flame which enables them to get very close to the metal without actually touching it with the flame. You will have noticed that there was a very fine stream of metal left sticking to the rivet head, and whilst this thin layer would prevent the flames touching the plate, it would be thin enough to enable the rivet stem to be knocked out easily.

The question of appearance is a matter of opinion. Personally, I think that after a bolted structure a welded structure looks rather spidery, and at first does not look safe. Tests, however, have provided that welded structures are quite safe, but as far as appearance is concerned, after all, few steel structures claim to be works of art. After one has got used to a welded structure I think it looks quite as nice as a riveted one. Once I put up a welded pier close to a riveted one. When I first saw it completed it certainly looked spidery, but after having seen it for a few months, the other pier looked very clumsy, and one began to realise the great lumps of metal you got all over it, so I submit that it is just a matter of being used to it. Compared with the built up plates and girders, the welded pier looked very flimsy, but in my opinion, very neat. The pipe line joints were tested by pressure if they thought they required it. I quite agree there is a possibility of blow holes, but suffice it to say that I put in nine miles of pipe work, and I did not have a single failure. It is true you can go along and cut out and inspect welds, but I have done very little of that. I used to carry a pocket drill and microscope but I found them really useless. I am assured by the engineer who loaned me the Lindeweld film that they did have periodical tests at first but it was quite unusual to detect any leaks.

I will say that at the oil works where I did some work they showed me some oxy-acetylene welds which were subjected to 1,000 degrees F. and 900 lbs. to the square inch pressure. They were butt welds and they had not had a single weld blow, and the only test they had was when they turned the oil in. The engineer assured me although I was not doing any acetylene welding on his works at that time, he would not allow me to use any other kind of weld.

MR. COTTON : In the welding of aeroplane fuselages, does one not get a lot of distortion ? At the point where the heat is applied would one not get local hardening ?

MR. HELSBY : Distortion, of course, is one of the serious difficulties in welding, but if the job is properly designed to use the least amount of weld metal, then you should get no distortion. I can say A. V. Roe's get no distortion. One of the unfortunate things about welding is that you can bridge across wide gaps with the weld metal, but if you do this you use a greater amount of heat and you get

distortion, due to the relief of the rolling stresses in the metal. With a thinner weld, however, this does not occur. Therefore, with a thin weld you get a minimum distortion, due to the relief of stresses and shrinkage of the weld metal. At the same time, oxy-acetylene welding does not cool as quickly as arc, therefore the fibres of both the parent metal and the weld settle more slowly, and therefore adjust themselves as they cool, and if the welding is done in jigs there will be no distortion. As regard the hardening, it depends upon the metal you use. I am assured that when Avro's were experimenting they had trouble at first with hardening, but they have overcome this. The correct method is a very thin weld, the correct size of flame, and the correct filler rod. In using the blow-pipe one has to make use of the various sizes of flame possible, for a small job one should use a small pip and for a big job a big pip. If the welder uses the right technique and he is given the right material to work with, he will produce a job that does not harden. If he is given a metal that hardens on heating, he will naturally produce hardness and that metal will not be suitable. I therefore consider the question of hardness is one of the metal you use.

MR. WILLIAMS: With regard to aluminium welding, what is the best known stick and the best flux to use? With regard to washing after welding, is hot water the best thing to use, or is there any special washing medium? I noticed on the film dealing with stellite welding that the flame was playing on the welded stellite. Is this essential with stellite welding? Regarding the Lindeweld blow lamp, does the use of this lamp overcome what may be termed the "human element?" That is, would the use of the Lindeweld lamp by a semi-skilled worker yield such good results as the use of an inferior type of lamp by a skilled worker.

MR. GORDON: The lecturer mentioned the words "fabrication" and "fabricator." What exactly do those words mean? May I take it that the word "fabricator" means the client, or is it the contractor, and that "fabrication" means the composition of a construction?

MR. HELSBY: The steel work fabricator is the contractor who makes up the steelwork. On the job mentioned I designed the building for my client, the design was given to the fabricator who tendered for the job, and that is why I said I had a client who allowed me to specify that no bolts or rivets were to be used.

MR. GORDON: With reference to welded joints in high tensile steel, will these lend themselves to heat treatment? With reference to thin plate welding, does the lecturer suggest the blowpipe better than the arc for this work? There is a combination with hydrogen gas, is this used for large castings only? Is there any danger attached to the use of hydrogen? Does the arc lend itself

better to production than the blowpipe, say, on motor cars and such like ?

MR. KENWORTHY : On the film we were shown the welding of some stainless steel, I would like to know what was the welding medium and whether the weld is stainless as well as the parent metal. Another point that has already been mentioned, the question of welding high tensile steel with a nickel content. Are these steels as strong in the welded joint as in the original steel, and also is the structure of the metal altered, due to local heating. With regard to the question of appearance, the welds on the film seemed to be very rough. That might be quite suitable for that class of work, but I should like to know if the lecturer can give us any information with regard to the welding of delicate material where a neat finish is desirable.

MR. ATWOOD : I noticed in the film in the section showing aluminium welding that the operator hammered the weld after welding. Can the lecturer tell me the purpose of that ?

A VISITOR : Could the lecturer give us the analysis of some of the sticks used ? I am sorry no mention was made of bronze welding or the welding of dissimilar metals. I understand that the British Oxygen Co. claim that they can weld bronze on to other metals and that when contraction takes place the bronze will take the strain. Is that the case ?

MR. SELVEY : Has the lecturer any experience with welding in brass ? Will brass to brass spot weld ? If so, what is the specification of the brass ? With reference to the welding of stainless steel, has the lecturer heard of any trouble experienced with the burning of thin (.026) stainless steel and if so how is it dealt with ? Also can the lecturer give us any information how the welds are finished to give a clean job, on thin steel fabrication. We are having trouble with the steel burning before the welding metal fuses, necessitating the building up of the holes on completion, causing extra labour costs in the removal of extra weld to give the clean finish required.

MR. HELSBY : With regard to aluminium welding and the question of the best known stick and flux, in several of the questions I have been asked to recommend the best materials for different jobs, and I should like to say that it is quite impossible for me to answer questions of that kind, even if I had any preference for any particular article. The best thing to do, I think, is to submit a sample of the metal you require to weld to the makers of the filler rods, etc., and if they give you a guarantee with their product and the welder gives you a good weld, everything should be all right.

With regard to the washing of aluminium welds, this is done with warm water only as a rule. If any special cleaning material was necessary for any particular flux, the maker would specify this.

As regards " stellite " welding, I do not think it is essential to keep the flame on to the welded portion of the work. If you will remember, there was a big bubble of " stellite " forming behind the blowpipe and doubtless the operator turned his flame on this to reduce it. I don't know if you noticed it, but he afterwards knocked it off with his " stellite " stick. I have seen this film so many times that I naturally have noticed most of these little points. The Lindeweld blow lamp naturally reduces the risk from the " human element," but I should not like to put a semi-skilled man on to any welding. Welding is a highly skilled operation. The unfortunate thing at the present time is that any man can get a blowpipe and say he is a welder. I hope that in time when Welding Trade Unions operate and will only accept a welder who is a welder and encourage youngsters to take up welding as a trade, that the general standard of welding will be raised. I do not advise using semi-skilled welders on any work, but suffice it to say that the Lindeweld pipe is better for all purposes. As regard welding high tensile steels, many high tensile steels do not lend themselves to oxy-acetylene welding, but there is a very big range that do and they will heat treat satisfactorily. Certainly oxy-acetylene welds in mild steel can be forged down to the same limits as the mild steel itself. With regard to high tensile steels, as in other materials, you are in the hands of the metallurgist. I am not a metallurgist, but if anyone has any particular question of this sort if they will submit it to me I will submit it to our metallurgist and he will answer it. As regards thin plate welding, arc or blowpipe, I think there is no question of the superiority of the blowpipe. As regards hydrogen, I think it is exclusively used for large castings and oxy-acetylene is not incompetent to deal with that class of work. As regards the danger of hydrogen, I think if this is properly looked after there is no danger. As regards arc welding for use on cars, frames, etc., I do not think there is any better performance. As regards stainless steel with nickel content, welding can be treated briefly in two sections. Mild steel and non-ferrous metals and special high tensile steels should be included with the non-ferrous metals. A sample of any special material must be submitted to the metallurgist of the supplier in order that he may specify the correct filler rod, and I think so far as the weld metals are concerned, you will find the suppliers only too pleased to supply any information required. They have staffs of highly skilled metallurgists to deal with these questions.

With regard to the appearance of the welds in the film, you must understand that they were multiplied several times in the picture, and that the same weld seen natural size would appear much smoother. As regards welding of delicate materials, I can assure you that a short time ago I had some welded teapots sent to me with

the query " Puzzle, find the Weld," and it was only under a high power glass that I could detect the weld and another man argued with me for quite a long time about the position of the welds. The aluminium weld you saw in the picture required cold working in order to bring it to a state comparable with the parent metal, and that is the reason the weld was hammered. Bronze welding need not show any difficulty. If I had had the discussion before the paper was given, I could have supplied details. The trouble is everyone is not interested in this question, and the paper deals with questions of more general interest. With regard to the welding of disimilar metals, which the British Oxygen state they have done, I can assure you I have seen some samples as near perfection as could be obtained.

With regard to resistance welding and spot welding, this ought to have been a general paper. I will say, however, that spot welding is a commercial proposition, and one can spot weld aluminium and other metals quite easily. As regards the finish of stainless steel welds, I think I have spoken before, and with welds of dissimilar metals one can see the line of demarcation quite clearly, and on any welded job if one likes, one can grind it off and make it quite neat. On the 1,000 ton ship on the Tyne I spoke of previously they went along with a pneumatic chisel and left the weld looking as if it had been puttied, that is, quite smooth. That, of course, was on the welds that were exposed to view. I can assure you that a weld can be made very neat indeed if it is properly executed by an ordinary skilled man, and oxy-acetylene welding can be much neater than arc welding because it can be made actually flat by applying the lamp carefully. There were special reasons for some of the welds you saw in the picture being made wavy.